NASA Tech Briefs

Official Publication of the
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January 1993 Vol 17 No. 1

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Andrew's Aftermath

Ask six questions before purchasing a borescopic measuring system...

1. Is it accurate and repeatable?
2. Can it measure on curved surfaces?
3. Can it measure objects at any orientation?
4. Is it easy to use and learn?
5. Can it be used with all existing scopes?
6. Is it compact, rugged, and portable?

Wire-frame CAD model of turbine blade on IW-1 screen automatically conforms to digitized image of blade for measurement with new Olympus 3-D borescopic measurement system, despite blade orientation.

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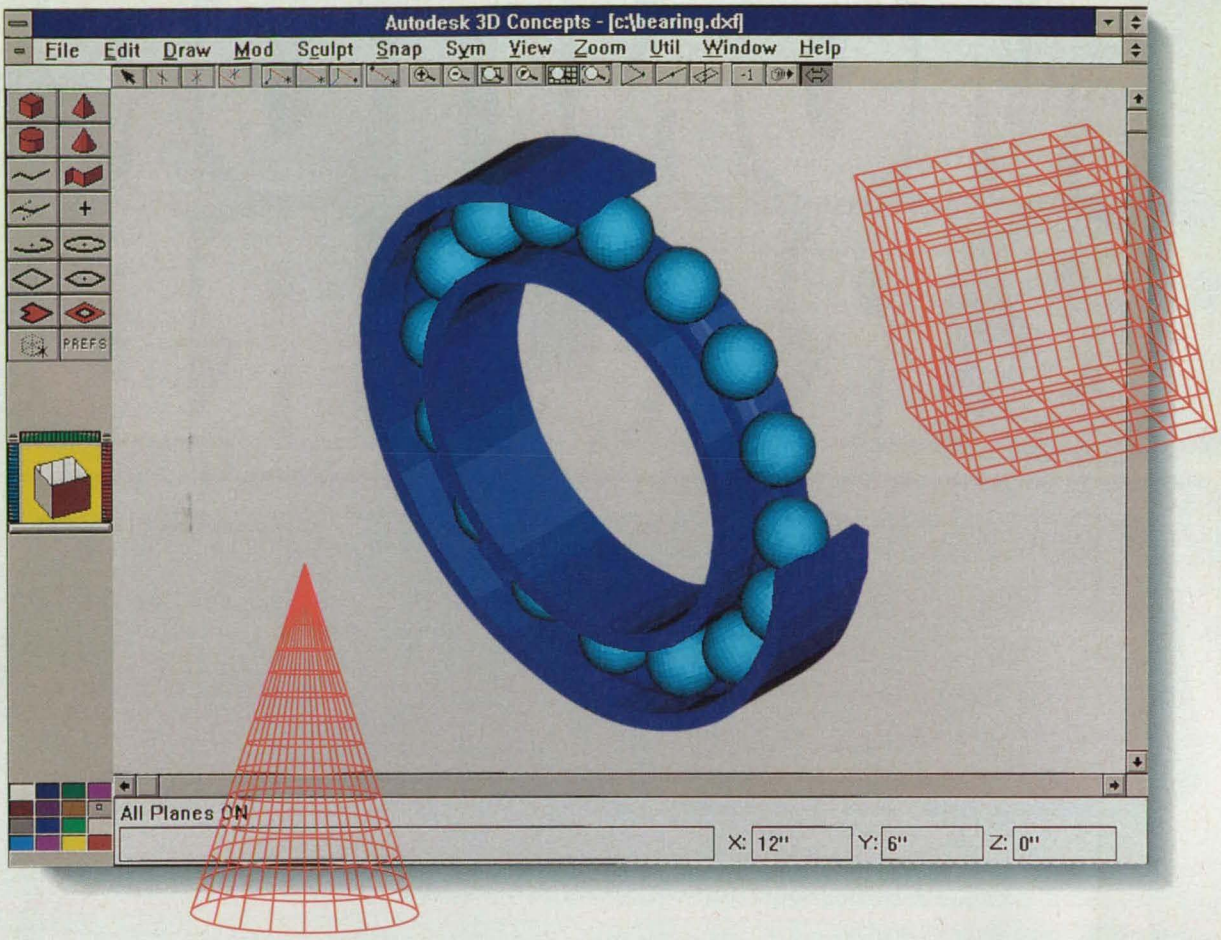

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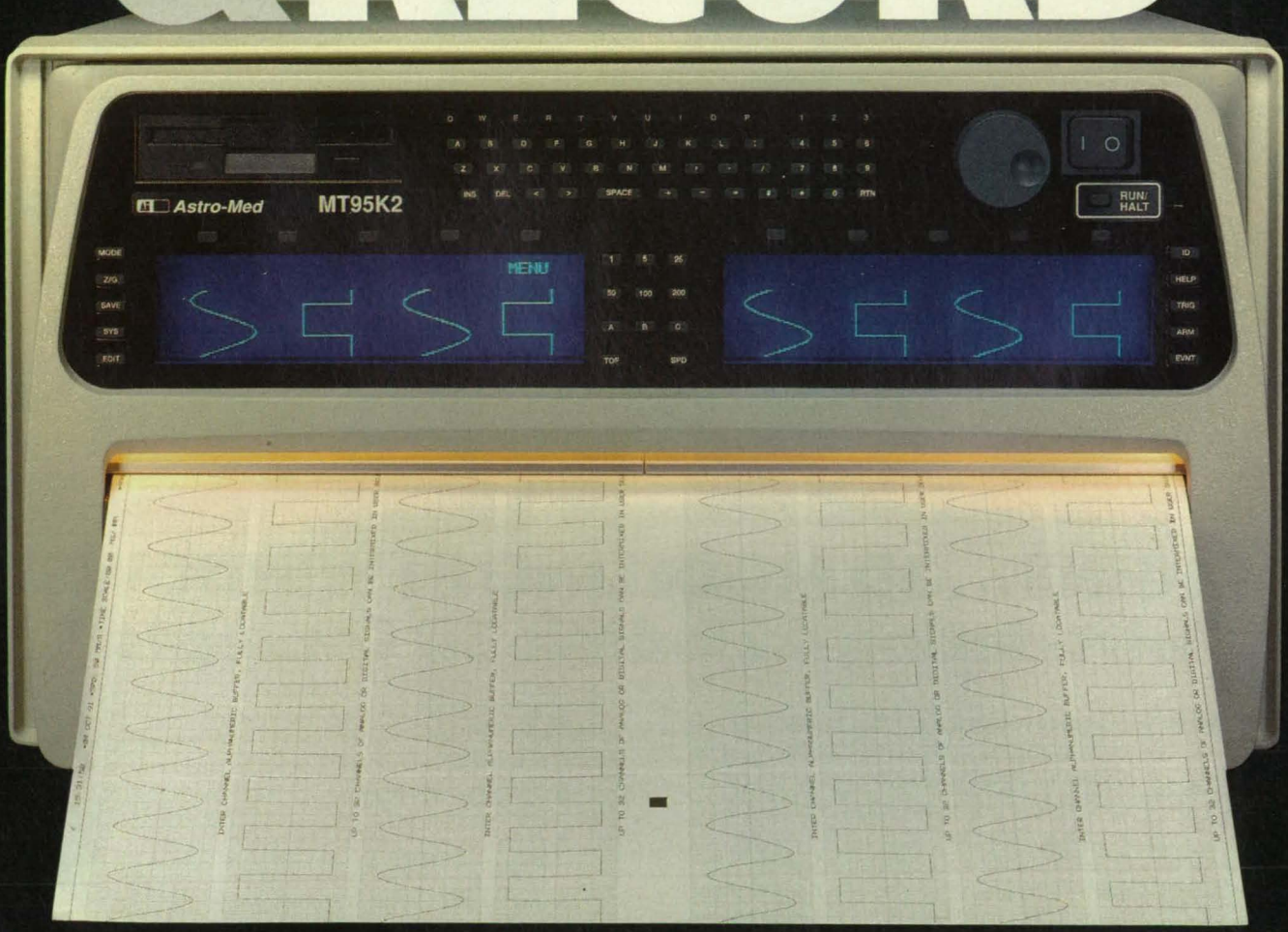

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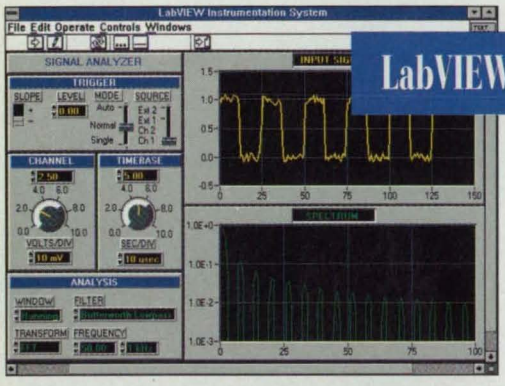

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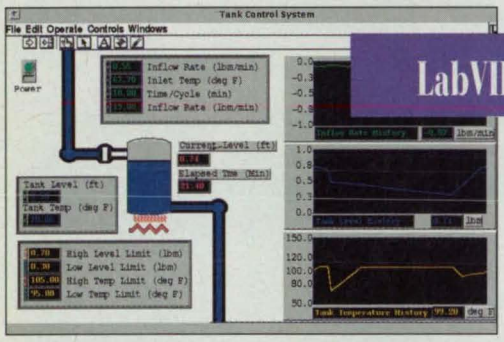
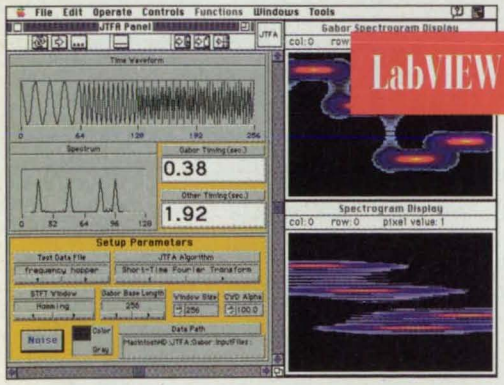


LabVIEW for Sun



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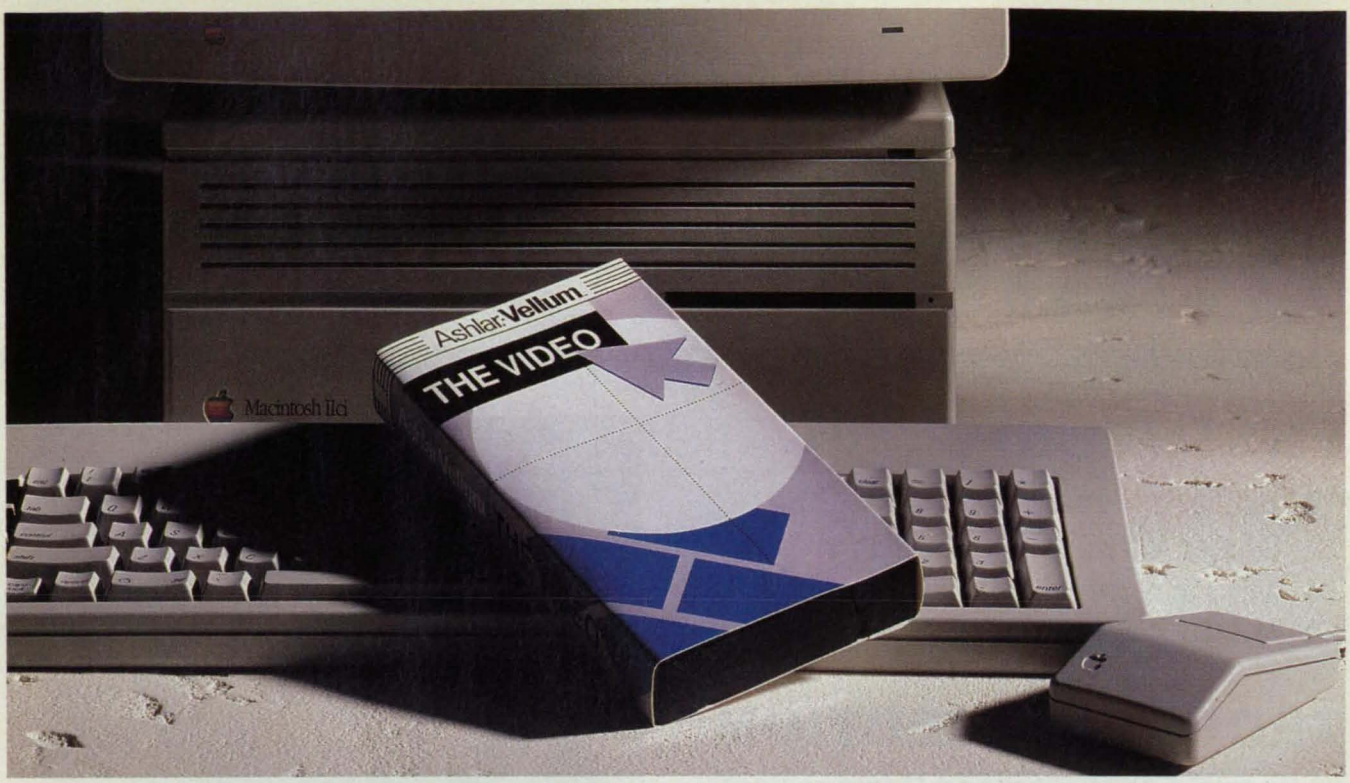

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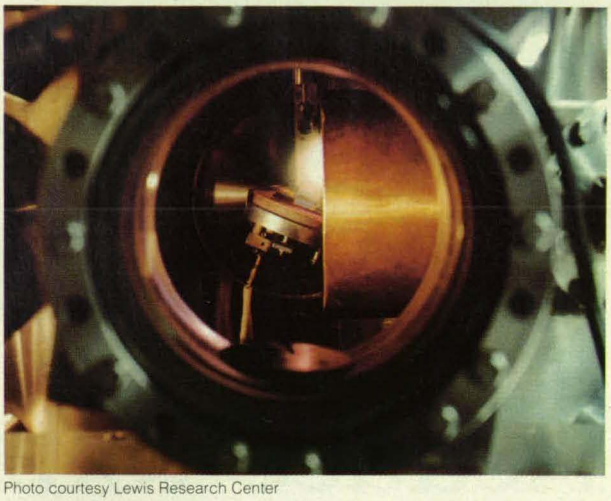

Photo courtesy Lewis Research Center

NASA Lewis researchers are investigating ways to incorporate high-temperature superconducting (HTS) materials into microwave circuits. The photo above shows a technique for depositing an HTS thin-film on a microwave substrate. This technology has the potential to reduce electrical losses in such components as ring resonators, filters, transmission lines, phase shifters, and feed lines in phased-array antennas. See the report on page 46.

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Contents *(continued)*

Photo courtesy Kennedy Space Center

Kennedy Space Center has developed a plant growth system (pictured above) that conserves water by supplying nutrient solution to seedling roots only as needed. The invention may have applications in arid environments.

ABP BPA

DEPARTMENTS

on the cover:

Images such as this one taken just days after Hurricane Andrew swept through southern Florida played an important role in the state's post-disaster assessment. The images, precise enough to calculate damage to individual buildings, were captured by Stennis Space Center aircraft equipped with NASA-developed remote sensing technology. Turn to Mission Accomplished, page 14.

Photo courtesy Stennis Space Center

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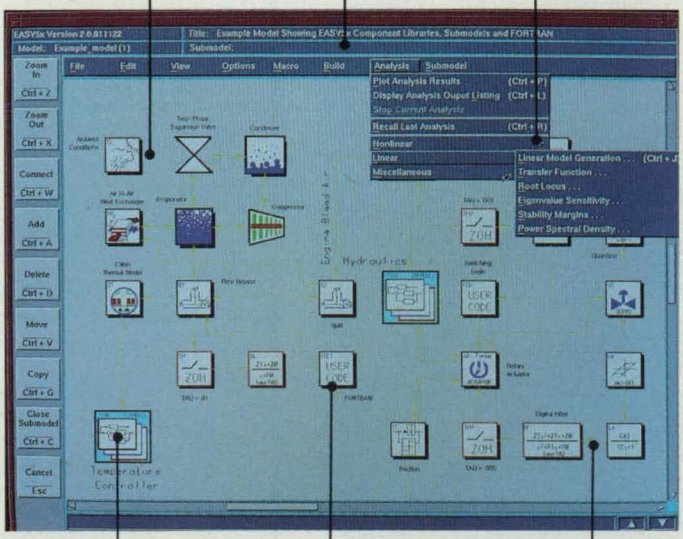

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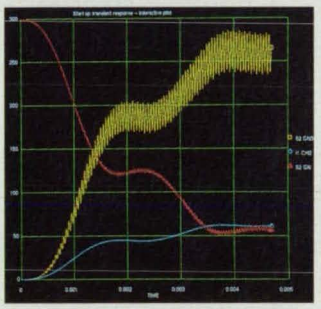

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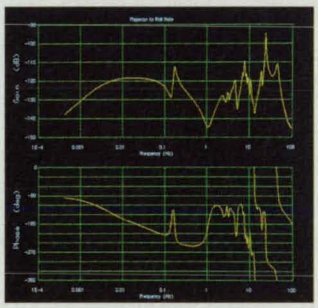

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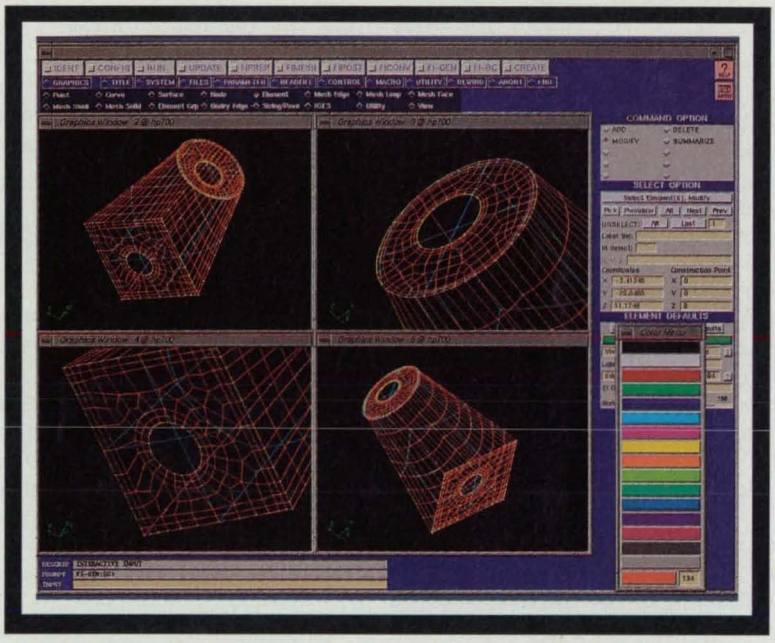

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Editorial Notebook

We're delighted to announce the winners of the 1992 Letter Writing Contest. A lot's been written about the lack of interest in science, math, and engineering among American children, and deservedly so, in my opinion. Less than half of the graduate engineering students at American universities are Americans and, unlike in previous eras, fewer and fewer foreign students elect to remain here after graduation. We're educating almost everyone but ourselves—and today's temporary "glut" in the engineering job market, thanks to corporate downsizing and a slow economy, doesn't mean we aren't facing a future famine. We are.

But you needn't worry about the winner of both the grand prize and children's prize in the contest, according to our Associate Editor, Sarah Gall. When Sarah called to notify eleven-year-old Adam Gulley that he'd won, she first spoke to his dad, an electrical engineer who confessed that he used to be a reader of *NASA Tech Briefs*. Now he's a reader of what Adam thinks are the most interesting tech briefs to share with his dad...because Adam gets *NASA Tech Briefs* first and marks the good parts. Adam saw the column in *NASA Tech Briefs* announcing the contest and entered himself, with no prodding from his dad. Indeed, Adam's brother Aron, age 9, also entered.

The adult winner, ceramic engineer Diane Folz, was as excited about winning as Adam, Sarah reported, and equally as eager to go to Space Camp. It is this kind of enthusiasm that needs to be communicated to our elected officials. As Mark Hopkins of Spacecause (the contest judges) pointed out, though the contest is over, the need to write, call, or fax Congress and the executive branch remains as exigent as ever.

Please, if you haven't written, do so now. Your future, your children's future, and the future of the country depend upon it. I hope you enjoy the following letters as much as we did...they've inspired *me* to get back at the keyboard and bang out some more letters.

Bill Schnirring

THE WINNERS: THE TOP LETTERS IN SUPPORT OF THE US SPACE PROGRAM

Grand Prize and Children's Winner

Adam Q. Gulley, Cleveland Heights, OH

Dear Representative Stokes:

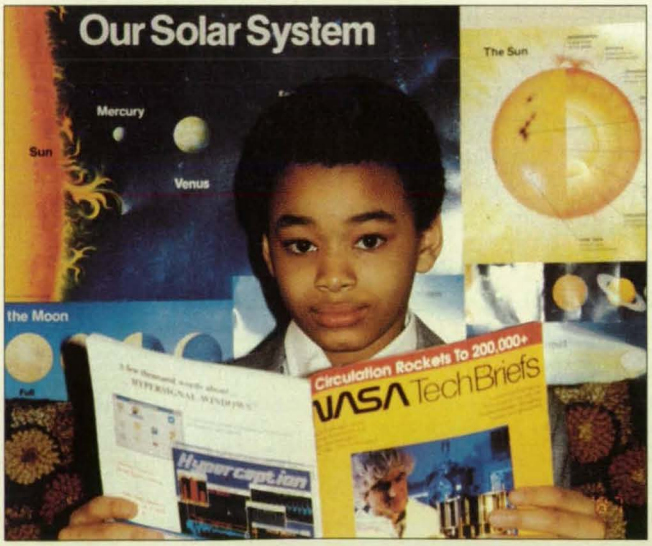
May I ask you to support the space station Freedom? It could serve as a laboratory for learning how to use the microgravity of space, making possible the materials which would help us all. Maybe we could even discover new ways of improving parts on cars. I'm sure you remember that before the space program, we didn't have very long mileage tires for cars. Now we do. Satellites help us talk to people and watch TV all over the world. If it wasn't for the space program, we wouldn't have these technologies.

Freedom could help us answer many questions and problems. We may find cures for terrible diseases that scare us such as AIDS, cancer, leukemia, and Alzheimer's.

It has been estimated that the space station Freedom program will employ more than 70,000 people in at least 40 states. These jobs will contribute new ideas, new knowledge, and new products to our economy. Perhaps even I will be among those employed because of space station Freedom. I hope to do something in the field of space someday. But I still have a lot of studying to do.

So please, Mr. Stokes, support the space station Freedom.

Sincerely,
Adam Q. Gulley



Adam Gulley, 11, is schooled at home by his mother, Mildred. His father Dan, an electrical engineer, describes Adam and his younger brother Aron as "space nuts" who have both dreamed of going to the US Space Camp. Adam has won a tuition-free stay at the camp, and the family hopes to send Aron as well.

Adult Prize Winner

Diane C. Folz, Gainesville, FL

Dear Senator Gore:

In the economic and political climate of our country today, we can hardly justify giving up the tremendous driving force behind a major portion of our commercial successes. Over the past 12 years, we have allowed foreign competitors to walk away with billions of dollars worth of enabling technologies. Weakening the space program will undermine one of our few remaining opportunities to regain our competitive posture in the global marketplace.

There are those who espouse that "sending money into outer space is ludicrous when people are starving in our cities." However, creation of new products, medical advances, environmental technologies, and the host of vital new materials developed as part of the space program will have far-reaching effects that will increase the quality of life for **ALL** citizens.

There is little doubt that humankind is at best when reaching beyond perceived limitations to achieve the "impossible." Economic security is a by-product of scientific adventure. Can we really afford to suppress technological pioneers? Can we afford to wave off the opportunity for our children to experience the wonder of exploration? What an empty legacy ... what a message of hopelessness ... how much less than our parents left us.

A sincerely concerned citizen,
Diane C. Folz

Diane Folz, 34, is a ceramic engineer working at the University of Florida in Gainesville, from which she received her BS in materials science and engineering in 1987. She currently is president of the American Ceramic Society, Florida section, and secretary treasurer of the National Institute of Ceramic Engineers. She has won a tuition-free stay at the US Space Camp.

We would like to award honorable mentions to the following letter-writers and to thank everyone who participated in the contest:

Michael Alesso, Bakersfield, CA
Georgia Anderson, Memphis, TN
Mark Armstrong, Seattle, WA
Lisa Atzman, Rego Park, NY
Philip Barnes-Roberts, Altadena, CA
Gene A. Barton, Carson City, NV
Thomas R. Belden, New Vienna, OH
Brian Blake, Woburn, MA
Don Blose, Riverside, CA
Michael M. Boyle, Elk Grove, CA
Dale Brackman, Helena, MT
Olin Brown, Lynnfield, MA
Becky Brunette, Green Bay, WI
Amy Michele Burns, Landrum, SC
Michael Burrell, Tacoma, WA
Joseph C. Cain, Tallahassee, FL
Robert L. Campbell, Poway, CA
Barrie Carlson, Phoenix, OR
Paul Cartwright, So. St. Paul, MN
Norman F. Chance II, Indianapolis, IN
David Cherne, Harbor Springs, MI
Cherilyn Chin, Oakland, CA
William F. Clapp, Stratham, NH
Judith G. Clark, Cottage Grove, OR
Henry B. Classe, Fort Smith, AK
Carolynn Lee Conley, Houston, TX
Norman L. Cook, Monrovia, CA
Kathleen Cortese, Burbank, CA
Jessica C. Crandell, Ridgecrest, CA
Alison Daigle, Hoover, AL
Jared M. Dame, Ridgecrest, CA
Darrick K. Dean, New Castle, PA
Natalie Deans, Hoover, AL
Paul DeGeorge, Valley Stream, NY
Connie Dishong, Sherman, TX
Kyson Dominguez, Hoover, AL
Renee Durette, Merritt Island, FL
Leslie Esseck, Inverness, FL
K. Evezich, Kitteridge, CO
Mary Fedde, Huntsville, AL
Ronald M. Fish, White Plains, NY
W.G. Foerster, Kiel, WI
Roland A. Foulkes, Gainesville, FL
Floyd Fowler, Severn, MD
Richard & Cheryl Ann Ganci, Minnetonka, MN
Dr. & Mrs. Charles A Gaston, Poughkeepsie, NY
Michael Dean Gibson, Long Beach, CA
Mike Girdwood, Perth, ONT Canada
Robert Graham, Huntington Beach, CA
Herbert Greenberg, Springfield, NJ
Aron C. Gulley, Cleveland Heights, OH
Jemma Harbaugh, Caraopolis, PA
Dian L. Hardison, NASA
Luise Heitz, Greenlawn, NY
Blake Herring, Birmingham, AL
Alfred C. Hexter, Ph.D., Kensington, CA
Frank L. Hicks, Jr., Park City, UT
Arthur Horbach, Doylestown, PA
Jennifer Jager, Harrisonburg, VA
Michael J. Jaski, Elk Grove Village, IL
Joshua S. Johnson, Dubois, WY
John A. Jossy, Union City, CA
M.S. Kaminaka, Arroyo Grande, CA
Carl F. Knoll, Jr., Allentown, NJ
Erich Kring, Washington, MI
Darrell H. Lack, LaCrescent, MN
Tony Lariccia, Erie, PA
Amanda Lavender, Birmingham, AL
Jamie Lennon, North Plainfield, NJ
Ilia Linka, Cambridge, ONT Canada
Steve Lovoy, Birmingham, AL
Richard G. Lugar, Washington, DC
Laureen Macko, Charlotte, NC
Frederick Marich, San Mateo, CA
Ian S. Martin, Holland Patent, NY
Jimmy Martin, Hoover, AL
Jessica Ashleigh-Thorne Matthews, USAF Academy, CO
Ken Montanye, Butler, NJ
Michael R. Morehouse, Anaheim, CA
William J. Naivar Jr., Lithia Springs, GA
Abbas Naqvi, Birmingham, AL
Sarah K. Noble, Big Lake, MN
Chet Novak, Simsbury, CT
Dennis J. O'Neill, Pembroke, MA
Chris O'Quier, Mt. Vernon, OH
Mike Otis, Aberdeen, SD
Patrick Paolone, Birmingham, AL
Ronald Peck, St. Petersburg, FL
Glenn & Susan Petrie, Bartlett, IL
Mary Pffifer, Mt. Vernon, OH
Linda L. Williford Pifer, Ph.D., Memphis, TN
Daniel Pinkoski, Harker Heights, TX
Charles Poirier
Pattie R., Mimbres, NM
Nancy Ralston, Tequesta, FL
Elizabeth D. Ray, Corona, CA
Gary Rice, Albany, IN
Robert G. Roberts, Newington, CT
Heidi Robinson, Stonington, CT
Susan K. Rawson, Simi Valley, CA
William David Rice Jr., Vero Beach, FL
George M. Ruby, Des Moines, IA
Steve Russell
Henry Salisbury, Chula Vista, CA
Michelle Santoro, Hoover, AL
David Schwartz, Susanville, CA
Paul S. Shanley, Auburn, AL
David Shapiro, Colmar Manor, MD
Brent Sherwood, Huntsville, AL
Barbara L. Sieg, San Jose, CA
Amy J. Simpson, Yonkers, NY
Robert Sorenson, Berwyn, IL
Steven A. Sousa, Hyde Park, MA
Kristen Spangler, Lewisberry, PA
Wayne Spencer, Suffolk, VA
Juanita Starr, Soldotna, AK
Kyle Stewart, Birmingham, AL
David Strain, Higbee, MO
Juston L. Stratemeyer, Metropolis, IL
Rema Summers, Smithfield, NC
Joseph S. Swartz, Alta Loma, CA
John Tait, Kennewick, WA
Chas. B. Kaloli Taliferro, Hawaii City, Hawaii
Steven Tauber
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Samuel Dale Theller
Ashley Thigpen, Birmingham, AL
Philip Mitchell Torrance III, Spokane, WA
Philip W. Tracey, Cupertino, CA
Wade Trimm, Hoover, AL
Corrina Tuemp-Nishi, Vancouver, BC, Canada
Julie Twardowski, Wilmington, DE
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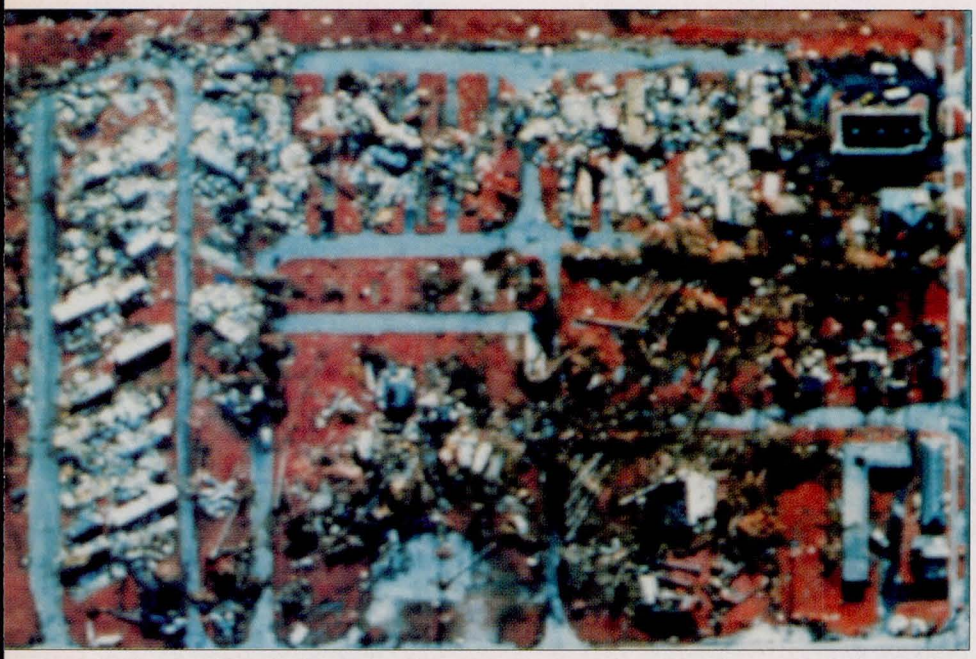
Donna T. Weeks, Bakersfield, CA
Marc Weiss, Edison, NJ
Mark Westphal, Yardley, PA
A. Wilson
Meredith Wilson, Hoover, AL
Jeni Wozniak, Flushing, MI
Antoinette S. Zabala, San Jose, CA

Mission Accomplished

Through the technology transfer process, many of the systems, methods, and products pioneered by NASA are reapplied in the private sector, obviating duplicate research and making a broad range of new products and services available to the public.

Flying swiftly in the wakes of hurricanes Andrew and Iniki, NASA aircraft captured images of destruction vital to accurate damage assessment.

Shortly after Hurricane Andrew had bypassed NASA's Stennis Space Center to the north this past August, the Mississippi facility received appeals from Florida to collect images for post-disaster assessment along the storm's path. Aircraft loaded with remote sensing technology and cameras arrived in Florida on August 28, four days after Andrew's initial strike. Images, first of urban areas and then natural environments, were collected August 29-31.



NASA-developed remote sensing technology captured images of Florida after Hurricane Andrew (see detail above) which, when compared with images taken prior to the storm (see below), enabled lawmakers to assess losses on a precise, building-by-building basis.

"We provided the first assessment of actual dollar losses on a house-by-house basis," said Bruce Davis, mission pilot and a geographer at Stennis. "Most importantly, we responded quickly—this information is highly perishable because people start cleaning up immediately."

A week later, Florida's governor Lawton Chiles incorporated photographs and digital images captured by the Stennis crew into a briefing packet presented to the US Congress and state legislature. With the support of the images, according to Davis, the governor was able to secure adequate disaster relief funding for his state.

The digital data was acquired by the Calibrated Airborne Multispectral Scanner (CAMS), developed at Stennis for Earth observation. CAMS is a nine-channel scanning spectroradiometer with spectral bands that mimic those on the Landsat thematic mapper. The equipment was flown aboard a Lear 23 jet that also carried a 9" x 9" metric aerial camera.

The Florida images also can aid in assessing the storm-resistance of buildings and roads with an eye toward amending construction codes. Those that are digital easily can be integrated with existing land use planning, flood, and utility maps.

"There's definitely a role for NASA to play in disaster assessment," said Davis. "We have the equipment, expertise, and remote sensing technology to provide useful data to state governments, the Federal Emergency Management Agency, the National Parks Service, and other organizations."

CAMS also is being investigated for commercial uses such as market analysis in the telecommunications industry. The Earth Observation Commercial Applications Program, which establishes one-to-three year joint ventures between Stennis and industrial partners, provides a means to integrate the technology into a business environment.

In February, Stennis will expand its remote sensing capabilities with a new instrument called ATLAS (Airborne Thermal/visible Land Applications Scan-

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Concurrent	Intergraph	Sequent
Convergent	Motorola	Silicon Graphics
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ner), a 15-channel scanner that goes directly to digital tape.

"The ability to use ATLAS data right away could be especially useful in disasters," said Davis. ATLAS will be joined with CAMS and TIMS, the thermal infrared multispectral scanner, to form the Airborne Instrument Test System. Potential commercial applications of the new system include environmental monitoring, facilities management, and mineral exploration.

NASA Helps Hawaii

Just three weeks after Andrew, Hurricane Iniki roared ashore in Hawaii. An urgent request from the state's Office of Emergency Planning for high-altitude aerial images brought a quick response from NASA's Ames Research Center in California.

"We got the call on Monday, had a team in Hawaii on Tuesday with 5000 pounds of equipment, and were in the air Wednesday morning," said John Arvesen, Ames' high altitude missions branch chief, who directed flights over the entire state with special emphasis on hardest-hit Kauai island. "Most importantly, we assessed lost vegetation and determined

An ER-2 aircraft (pictured in foreground) from Ames Research Center captured high-altitude aerial images over the state of Hawaii to assess Hurricane Iniki's impact.

storm surges to help develop new setbacks for properties."

The mission was undertaken by an ER-2 aircraft carrying a commercial scanner similar to CAMS and cameras to collect black and white, color, and color infrared images. Flying at 68,000 feet, the plane can acquire data similar to that gathered by space-based satellites.

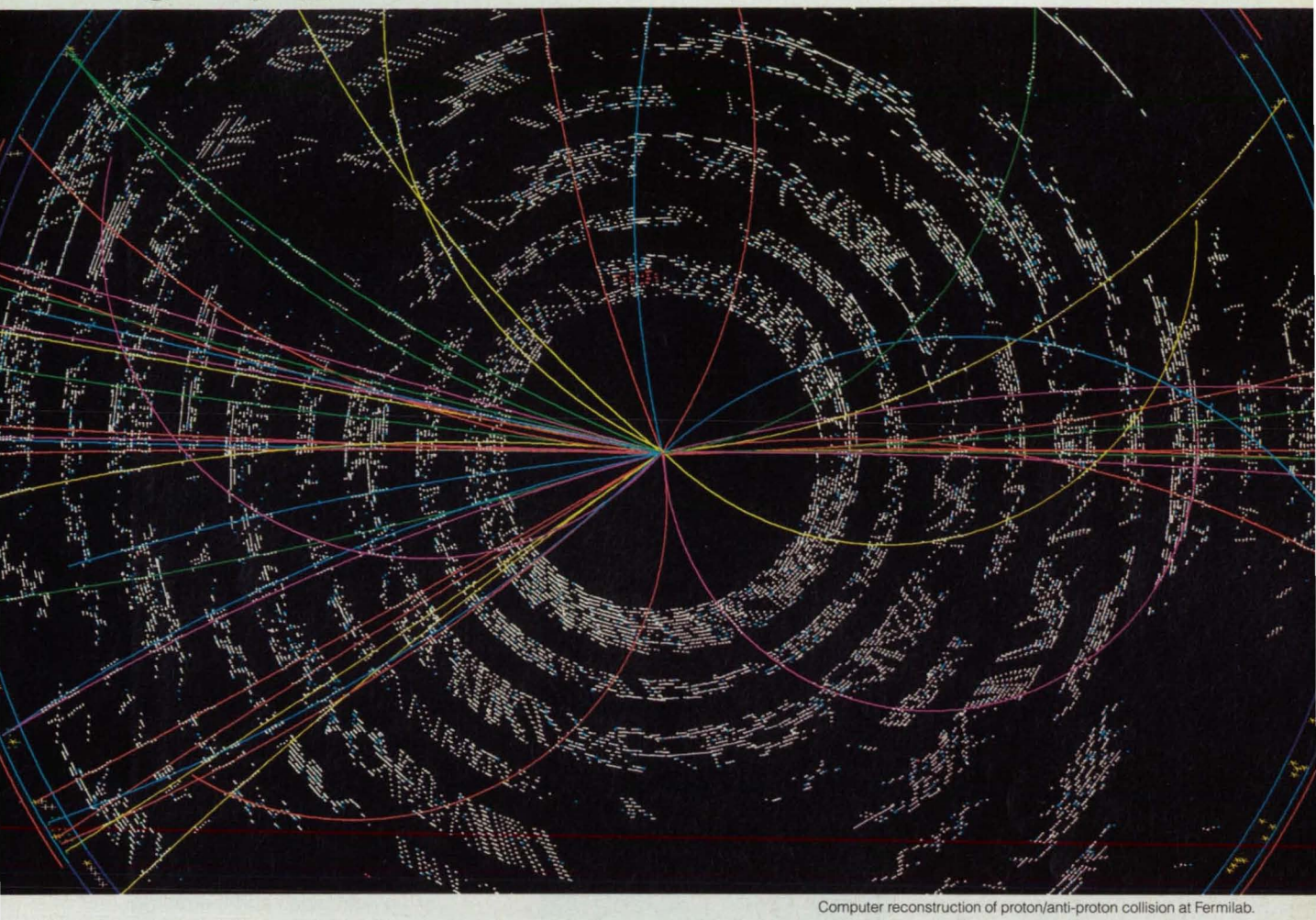
Initially, the images helped to pinpoint and map areas that suffered major damage to buildings and structures, to plan access routes and mobilization areas for work crews, and to make accurate cost estimates for presentation to state and federal legislatures. Subsequent uses included identification of forest and wetland damage, documentation of changes to shorelines and stream courses, and location of fallen trees and landslides obstructing trails and remote roadways.

"The NASA aircraft and equipment are uniquely qualified to respond to disasters," said Arvesen, who recalled that Ames was called in during the Yellowstone, Oakland, and Yosemite fires and after the San Francisco earthquake.

Ames and Stennis are coordinating additional missions in Florida, Louisiana, and Hawaii. These return trips will assess both regrowth and lingering damage to natural and urban resources, and examine particular areas such as the Florida Everglades. ❑

For more information about the technologies described in this article contact Bruce Davis, Mail Stop HA30, Stennis Space Center, MS 39529, or John Arvesen, Ames Research Center, Mail Code N240-6, Moffett Field, CA 94035.

Highly parallel computing.



Computer reconstruction of proton/anti-proton collision at Fermilab.

Fermilab is tapping a new source of power.

If there's one thing you can count on in science, it's that your data will increase exponentially but your funding won't.

The scientists at Fermi National Accelerator Laboratory (Fermilab) have encountered this problem in a very big way. The data Fermilab processes for subnuclear event reconstruction and modeling has reached 40 terabytes a year. And they've developed an innovative solution to meet their needs.

Instead of relying on supercomputers, Fermilab has distributed a significant part of the workload to clustered IBM RISC System/6000® workstations. They've combined 108 of them, at latest count, in a LAN-connected processor farm.

"The result," as Thomas Nash, Head of Computing at Fermilab puts it, "is better science." At a fraction of the cost of using supercomputers.

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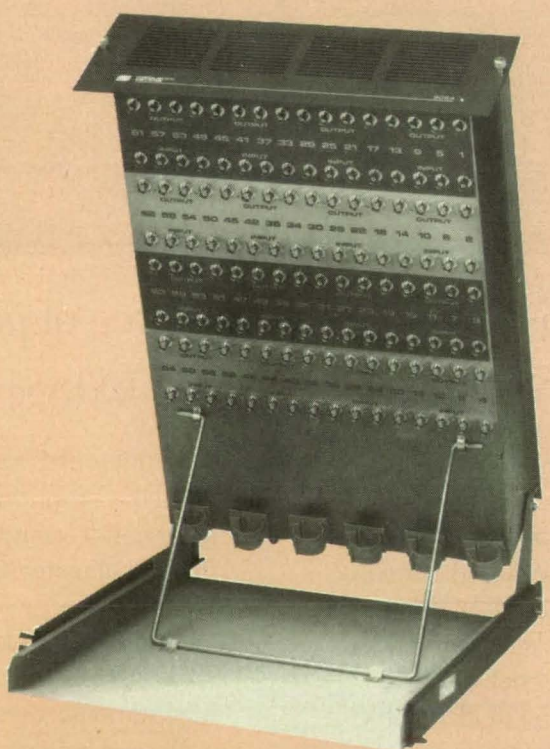
New Product Ideas

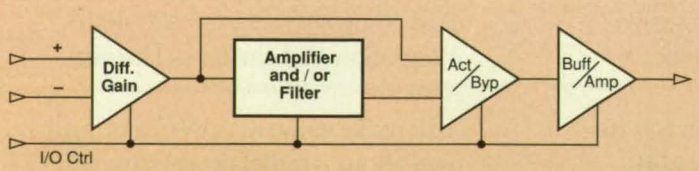
New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 20). NASA's patent-licensing program to encourage commercial development is described on page 20.

Self-Damping Sprung Wheel

This wheel includes its own shock-absorbing suspension for a wheelchair. Installed in place of the conventional large rear wheels on standard wheelchairs, the new wheel will reduce discomfort to users riding over rough surfaces.
(See page 70.)

MODEL 9064





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Improved Grid-Array Millimeter-Wave Amplifier

These amplifiers operate at millimeter and submillimeter wavelengths and are being developed for use in communications and radar. In the improved amplifiers, feedback is suppressed by making the input polarizations orthogonal to the output polarizations.
(See page 44.)

Robot Avoids Collisions With Obstacles

A developmental robot is equipped with infrared sensors and with a control system to allow the manipulator arm to move around obstacles. The robot can avoid collisions with other objects even when they are moving in unpredictable ways.
(See page 48.)

Mapping Temperatures on Heat Pipes

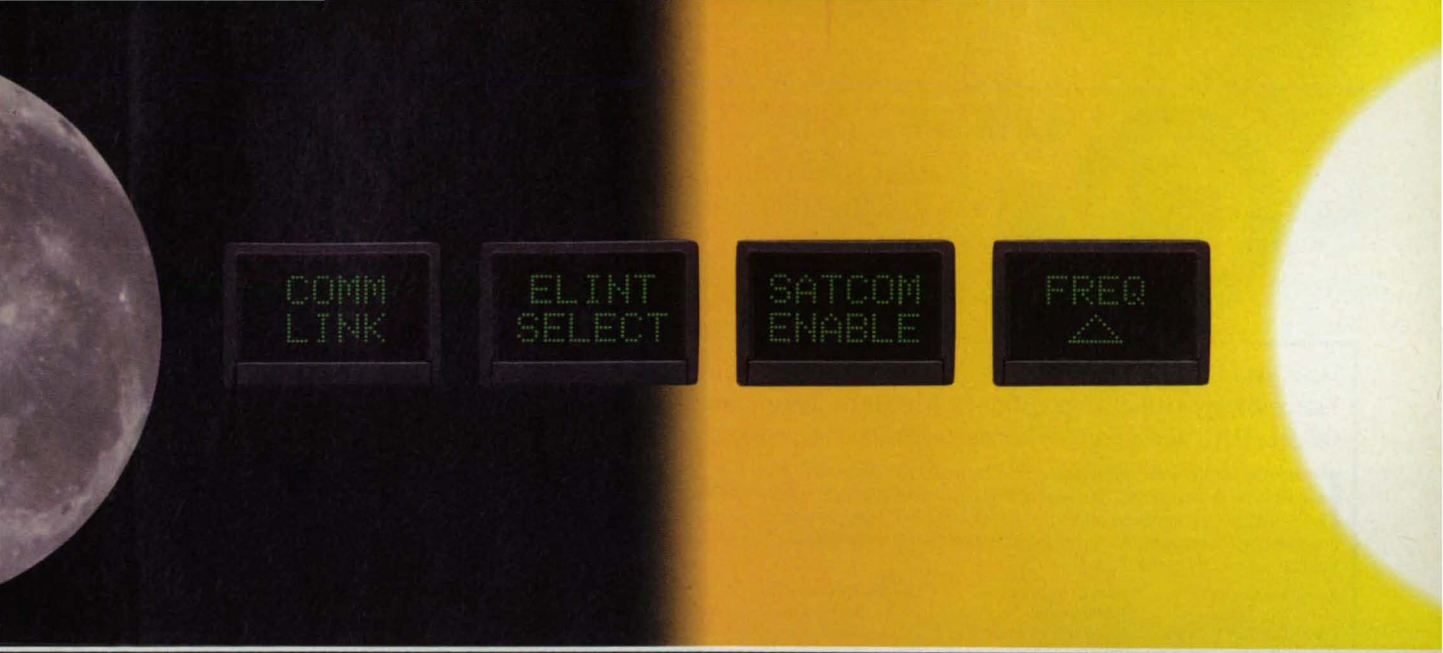
Paints containing thermochromic crystals can be used to map temperatures on heat pipes and thermosyphons. The color of such coats changes reversibly, each distinct color indicating a particular temperature.
(See page 58.)

Improved Composite Flexible Blanket Insulation

This insulation is a quilt of layers of advanced lightweight insulating materials, each optimized individually to inhibit the flow of radiative, conductive, or convective heat. The insulation can protect people and equipment against temperatures of up to 1,650 °C.
(See page 62.)

Poly(1,2,4-Triazoles) Via Aromatic Nucleophilic Displacement

This synthesis involves nucleophilic displacement of monomers with activated aromatic dihalides. The process opens up a large variety of new high-molecular-weight polymers that may be used in producing films, moldings, adhesives, and composites.
(See page 64.)



The NVIS-Sunlight Readable Electro-Optical Display System.

The VIVISUN 5000 electro-optical display system incorporates LED lighting that is both NVIS compatible and sunlight readable per MIL-L-85762A. This interactive system also provides rugged reliability and meets the environmental extremes that military programs demand.

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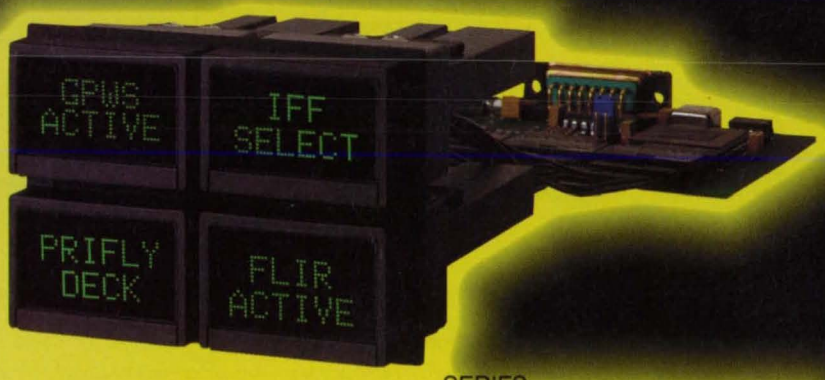

SERIES

VIVISUN 5000™

HOW YOU CAN BENEFIT FROM NASA's TECHNOLOGY UTILIZATION SERVICES

If you're a regular reader of TECH BRIEFS, then you're already making use of one of the low-and no-cost services provided by NASA's Technology Transfer Program. But a TECH BRIEFS subscription represents only a fraction of the technical information and applications/engineering services offered by this Program. In fact, when all of the components of NASA's Technology Transfer Network are considered, TECH BRIEFS represents the proverbial tip of the iceberg.

We've outlined below NASA's Technology Transfer Network—named the participants, described their services, and listed the individuals you can contact for more information relating to your specific needs. We encourage you to make use of the information, access, and applications services offered.

How You Can Access Technology Transfer Services At NASA Field Centers:

Technology Utilization Officers & Patent Counsels—Each NASA Field Center has a Technology Utilization Officer (TUO) and a Patent Counsel to facilitate technology transfer between NASA and the private sector.

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP). If a TSP is not available, you can contact the Technology Utilization Officer at the NASA Field Center that sponsored the research. He can arrange for assistance in applying the technology by putting you in touch with the people who developed it. If you want information about the patent status of a technology or are interested in licensing a NASA invention, contact the Patent Counsel at the NASA Field Center that sponsored the research. Refer to the NASA reference number at the end of the Tech Brief.

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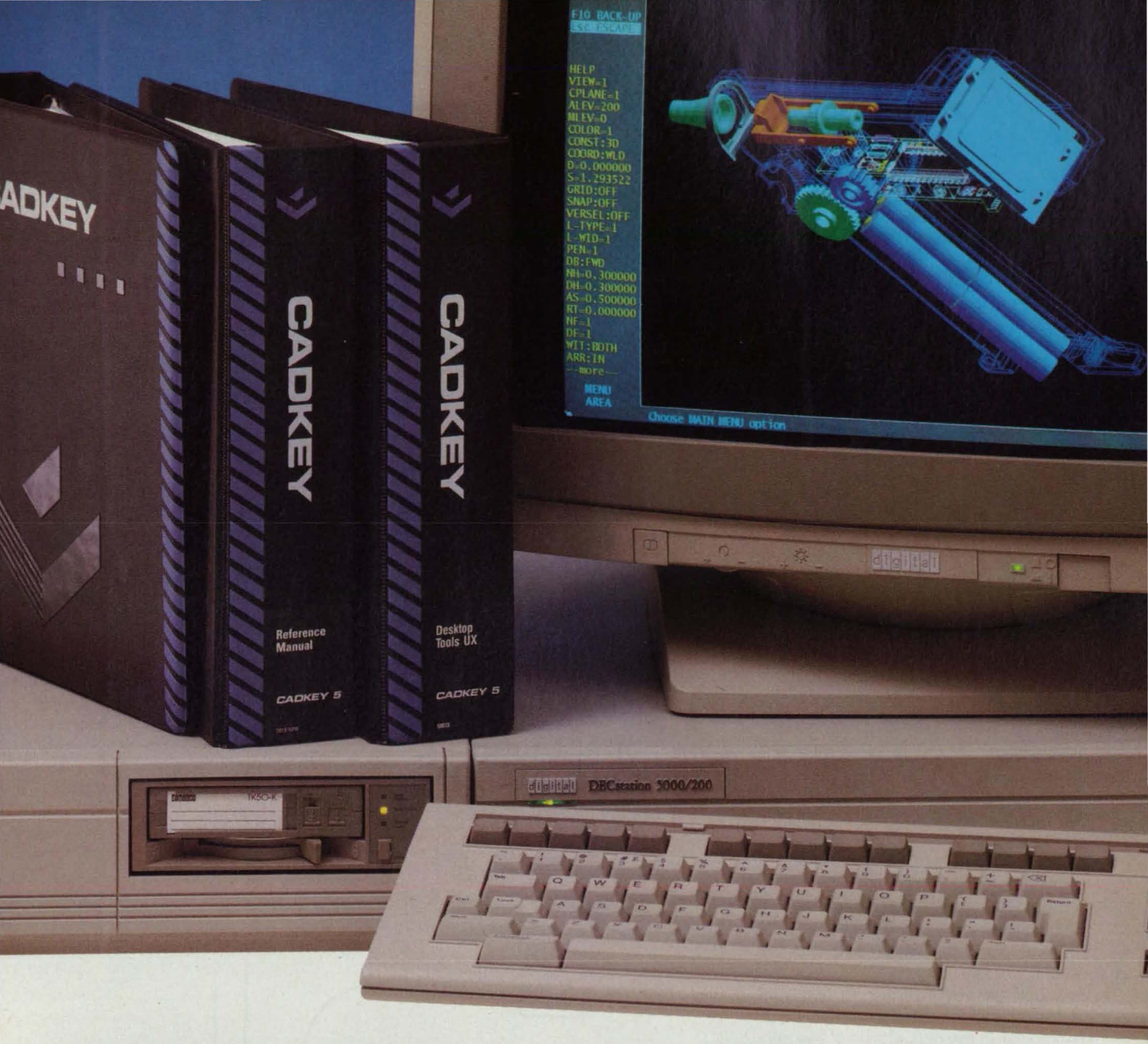

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Special Focus: Test and Measurement

Compact Raman Spectrometers Would Detect Hydrogen

Advantages would include speed, dynamic range, and ease of calibration.

John F. Kennedy Space Center, Florida

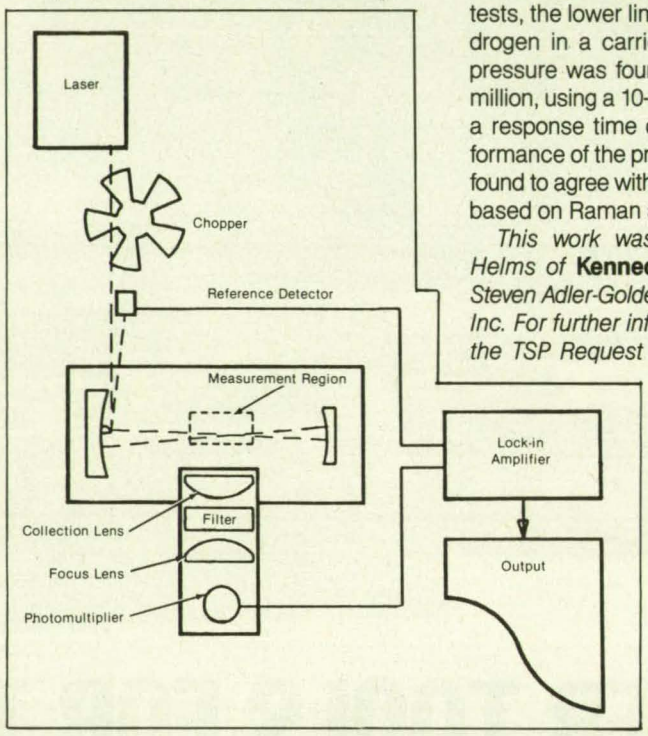
Compact Raman spectrometers are being developed to measure concentrations of hydrogen as low as hundreds of parts per million in air, nitrogen, or other carrier gases. Similar spectrometers could also be developed to detect other gases that emit characteristic Raman spectra.

The use of Raman spectrometry for this purpose is not new and has been described in several recent articles in *NASA Tech Briefs*. In this case, the novelty lies in a design concept that incorporates a Raman-scattering apparatus into a compact instrument that would measure the concentration of hydrogen leaking into a stream of gas or into a gas enclosed in a small space. The original intended use is the detection of leaks of hydrogen from rocket fuel systems; should hydrogen-fueled cars and trucks come into widespread use, instruments of this type could be used to detect leaks from vehicles and supply equipment, to help prevent explosions.

The figure is a schematic diagram of a laboratory prototype. A stream of the gas to be sampled flows through a chamber. Light from a helium-neon or argon-ion laser is directed past a chopper and into the chamber, where it is reflected back and forth between two concave mirrors. Light scattered from the gas approximately perpendicular to the optical axis of the concave mirrors is collected, then passed through a band-pass filter to remove Rayleigh-scattered light (at the laser wavelength) and background light. The emerging beam, consisting predominantly of light at the Raman wavelength characteristic of the hydrogen or other gas to be detected, is focused onto a photomultiplier tube. The output of the photomultiplier is fed to a lock-in amplifier synchronized with the chopper, and the output of the amplifier is sent to data-recording and -processing equipment.

Speed of response is one advantage of the Raman spectrometer: it has a characteristic response time of the order of seconds. In contrast, the response times of electrochemical hydrogen and oxygen sensors are of the order of minutes. It is capable of operation over the wide dynamic range from a few hundred parts per million to an all-hydrogen atmosphere. In tests, the lower limit of detectability of hydrogen in a carrier gas at atmospheric pressure was found to be 100 parts per million, using a 10-mW argon-ion laser and a response time of 2 seconds. The performance of the prototype instrument was found to agree with predicted performance based on Raman signal and noise levels.

This work was done by William R. Helms of **Kennedy Space Center** *and Steven Adler-Golden of Spectral Sciences, Inc. For further information, Circle 15 on the TSP Request Card. KSC-11441*



This Laboratory Raman Spectrometer has been used to test the concept of a compact Raman-scattering leak detector. A fully-developed instrument is expected to occupy a volume of 0.6 ft^3 (about 0.017 m^3), to weigh about 35 lb (about 16 kg), and to be capable of monitoring He, H_2, N_2, O_2, and Ar concurrently at 9 locations at 3 locations per second.

Test-Signal Generator for SNR Calibration

Analog signals with accurate signal-to-noise ratios will be synthesized digitally.

NASA's Jet Propulsion Laboratory, Pasadena, California

An assembly of commercial and custom-made electronic equipment is designed to generate noisy intermediate-frequency or baseband received phase-modulation data-communication signals with accurately known signal-to-noise ratios. The signals will be used to perform signal-to-noise-ratio calibrations and other tests of the responses of data-communication receivers to noisy incoming signals. This test-signal-generating system is intended specifically for use with spacecraft-telemetry receivers of the Deep Space Network, but the underlying principle is also applicable to the generation of test signals for other advanced data-communication receivers.

The test signal and test noise are generated by digital synthesis followed by digital-to-analog conversion. The subsystems of the test-signal generator (see figure) include a commercial personal computer, a custom-made signal-generator box, a test-support assembly (which feeds clock signals and externally encoded data signals to the signal-generator box), and a commercial frequency synthesizer.

The monitoring, controlling, and other signal-processing programs reside in the personal computer. Commands from the personal computer are sent to the central processing unit of the signal-generator box. In response to these commands, this central processing unit reconfigures the connections among various other high-speed subunits of the signal-generator box to generate the calibrated output signals. Oper-

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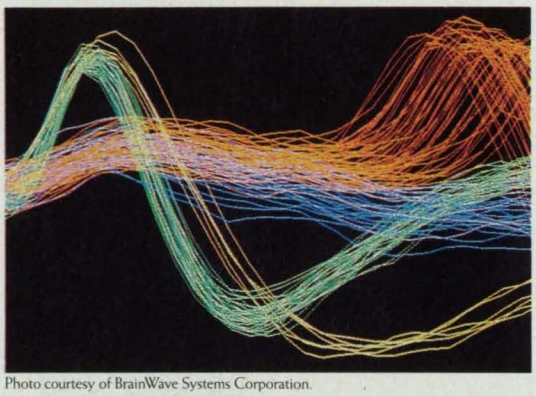

Photo courtesy of BrainWave Systems Corporation.

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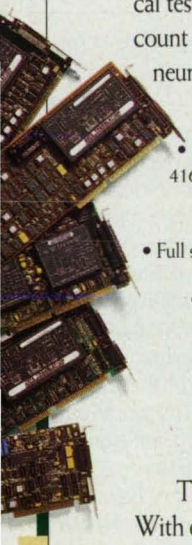

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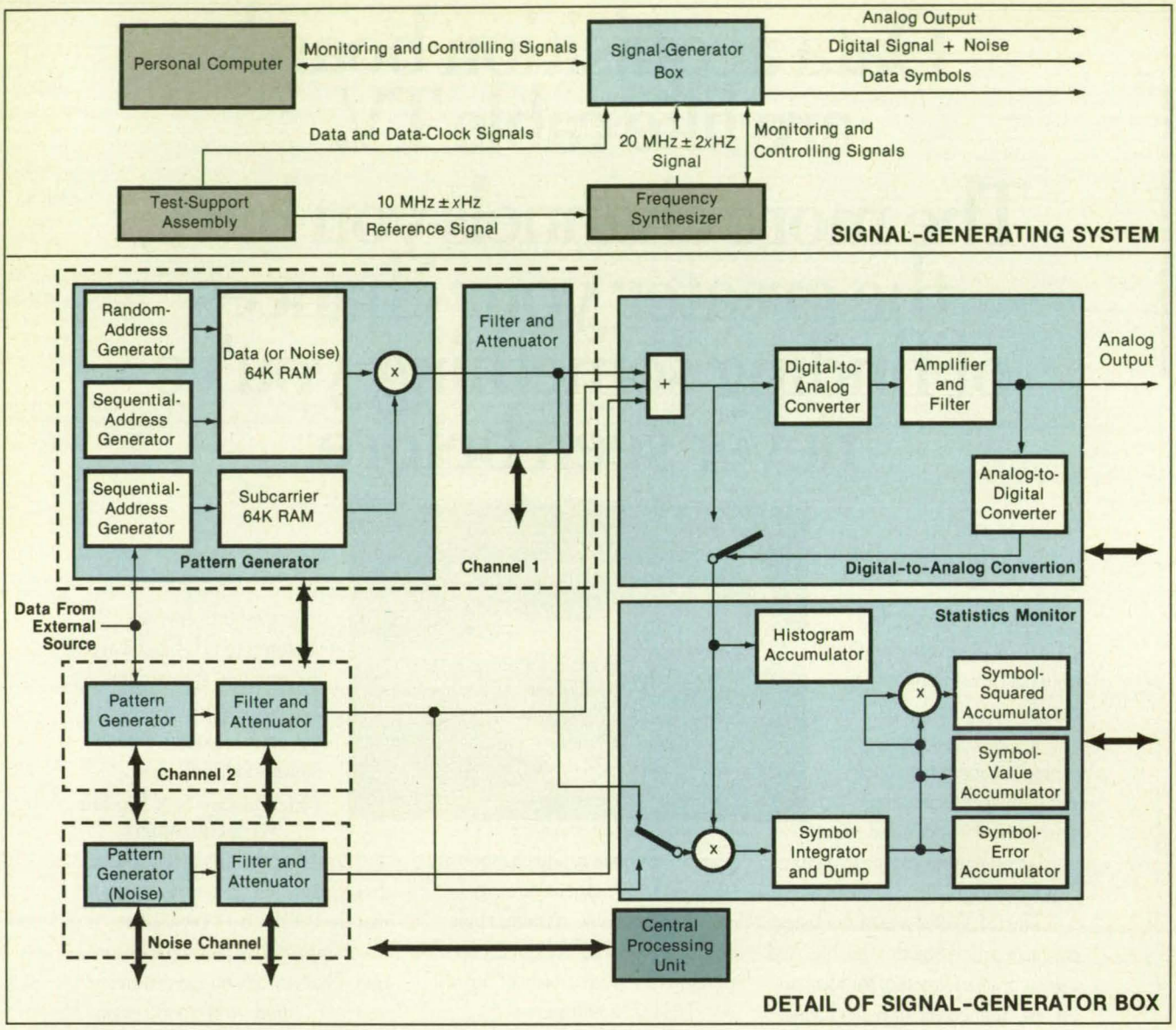


The **Test-Signal Generator** generates baseband or intermediate-frequency phase-modulation data signals plus noise with accurately known signal-to-noise ratios, by use of digital synthesis followed by digital-to-analog conversion.

ating in conjunction with the frequency synthesizer, the signal generator then produces the various signal spectra, including intermediate-frequency, dual-subcarrier, and/or quadrature-phase-shift-keying components.

The lower part of the figure illustrates the relationships among the functions and subunits of the signal-generator box. The pattern generator, when configured to generate noise, accepts data bytes from the central processing unit to be mapped into a random-access-memory (RAM). After the RAM has been loaded, it is read sequentially by a random-address generator, which is a pseudonoise code generator with inherently uniform output distribution and a period longer than 24 hours. The distribution function of the data bytes mapped into the RAM acts in conjunction with the uniform distribution function of the addresses with which this RAM is read to determine the distribution function of the output of the noise generator. Usually, the distribution function mapped into the RAM is a Gaussian distribution quantized to a specified number of bits from the corresponding analog probability function.

The main purpose of the filter-and-attenuator subunit is to synthesize low-pass filters defined by the user when generating a baseband spectrum or to synthesize bandpass filters when generating an intermediate-frequency spectrum. Noise and data are filtered independently by two digital filters. These filters can, if desired, have the same frequency response.

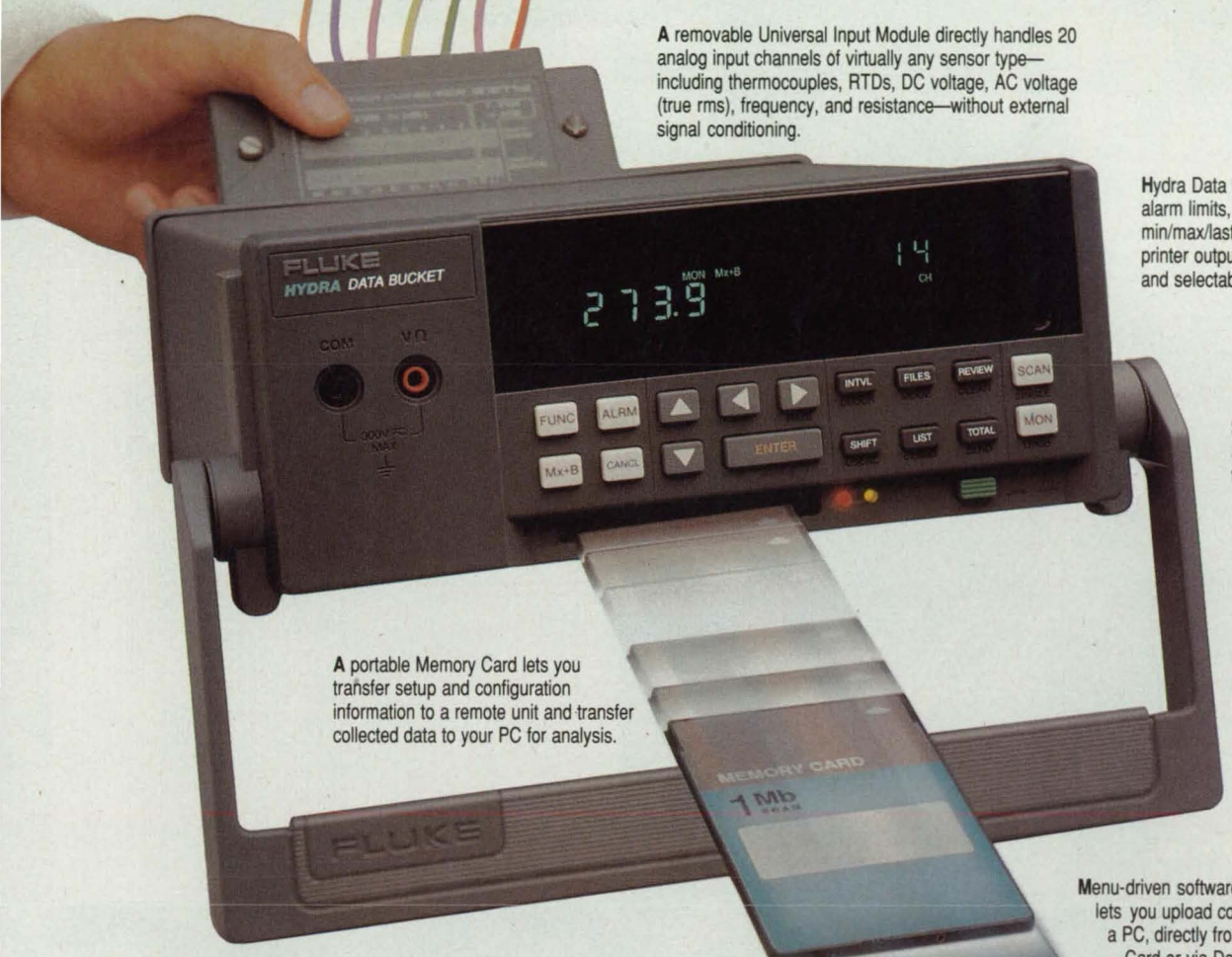
The function of the digital-to-analog-conversion subunit is fairly self-explanatory. The statistics-monitor subunit performs multiplication and accumulation functions to generate some statistical measures of the digital and analog outputs.

Overall, high accuracy is maintained by simultaneous generation of digital noise and signal spectra at a given baseband or passband. The digital synthesis provides a test signal embedded in noise with the statistical properties of a stationary random process. Accuracy depends only on test integration time, with a limit imposed by the quantization noise of this system (estimated to be 0.02 dB). The worst-case root-sum-square error on a given signal-to-noise-ratio setting is estimated to be 0.11 dB.

This work was done by Benito O. Gutierrez-Luaces of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 30 on the TSP Request Card.*

NPO-18495

When you can't be there,



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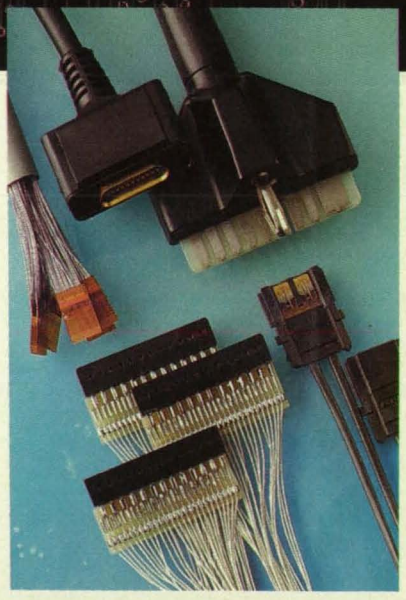

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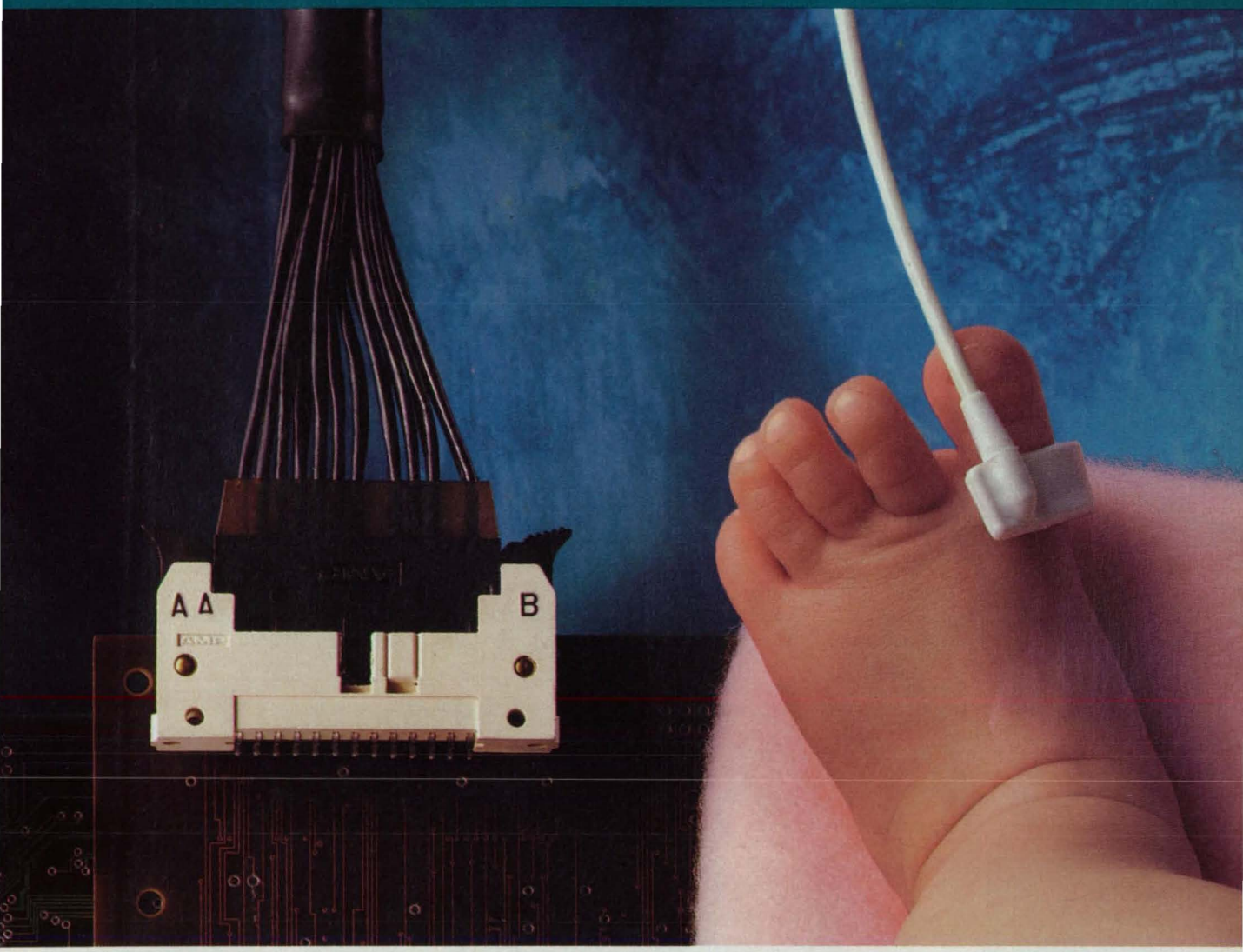

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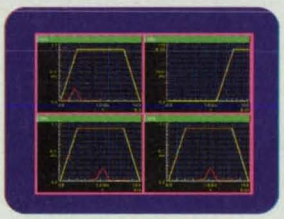

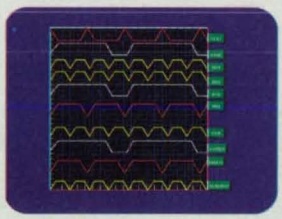

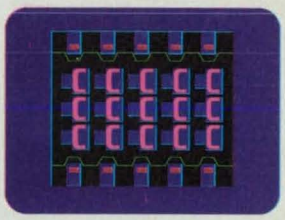

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X-Ray and Acoustic Measurements Yield Stiffnesses

Data from nondestructive tests are combined for use in calculating stresses and strains.

Langley Research Center, Hampton, Virginia

An analytical technique combines ultrasonic scanning measurements of the local velocity of sound in a specimen of material with x-ray computed tomographic measurements of its local mass density to compute the local stiffness of the material. The stiffnesses at various locations in the specimen can then be used in a finite-element mathematical model of the elastic behavior of the specimen to compute local stresses, local strains, and overall deformations. Thus, the new technique enhances the value of quantitative nondestructive x-ray and ultrasonic measurements. It is especially useful in the characterization of carbon/carbon composites and other advanced materials that are not homogeneous and for which the customary simplifying assumption of constant density and/or constant stiffness is not valid.

Figure 1 illustrates the main steps of the analytical technique. The x-ray computed tomographic images are processed to convert the data on the local absorption of x rays into local density with the help of either a reference sample of the same material having known density or else a conversion table for calibration. The processing of the ultrasonic measurements is more complicated because if the material is anisotropic, the velocity of sound depends on the direction of propagation; namely,

$$\sum_{j=1}^{3}\sum_{\ell=1}^{3} C_{ijk\ell}\alpha_j\,\alpha_\ell - \rho V_s^2\delta_{ik} = 0$$

where the $C_{ijk\ell}$ are coefficients of stiffness, α_j and α_ℓ are direction cosines of the propagation of the sound; ρ is the local density, and V_s is the speed of sound along the indicated direction. The direction cosines can be deduced by Snell's law from the angle of incidence of sound on the specimen and the measured speeds of sound in the specimen and in the coupling medium in which the specimen is immersed. The equation can then be solved by iterative numerical means to obtain the stiffness.

The velocity along a given ultrasonic-measurement path from the transmitting to the receiving transducer is measured in terms of the time of flight of a pulse or the shift in phase of a wave along the path. Measurements are taken with the transmitting and receiving transducers at various positions in the coupling medium and oriented at various angles with respect to the specimen (see Figure 2), using offsets calculated by considerations of refraction and energy-flux density paths. Because the time of flight or change in phase is an integral of the reciprocal of speed of sound along the path, the measured speed is, in effect, an average value that corresponds to this integral. Speeds of sound must be measured along multiple directions to include the effects of anisotropy. For example, an orthotropic material has nine independent coefficients of stiffness, requiring nine independent measurements of velocity for each position.

This work was done by Eric Irvine Madaras of **Langley Research Center** *and Ronald A. Kline of the University of Oklahoma. No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14108.

Figure 1. **X-Ray and Ultrasonic Measurements** are combined with an analytical technique to obtain more information on an anisotropic specimen than can be obtained by either technique alone. The combination yields data on the coefficients of stiffness, which can be used in a finite-element mathematical model of the elastic behavior of the specimen.

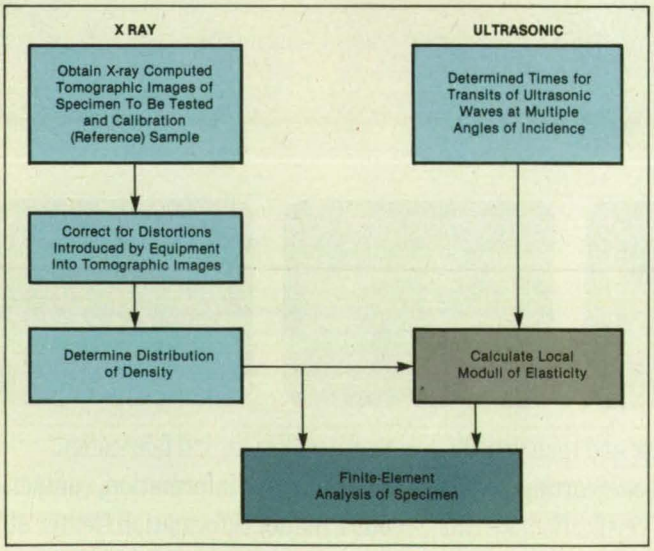
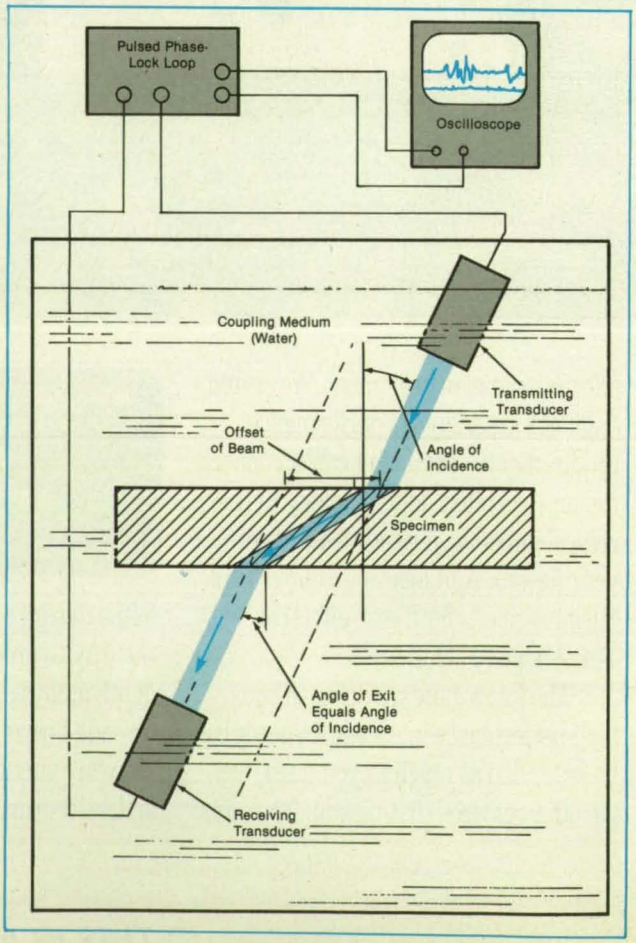


Figure 2. The **Speed of Sound** is measured along multiple paths through the specimen at various angles to obtain data on its anisotropic-stiffness properties.



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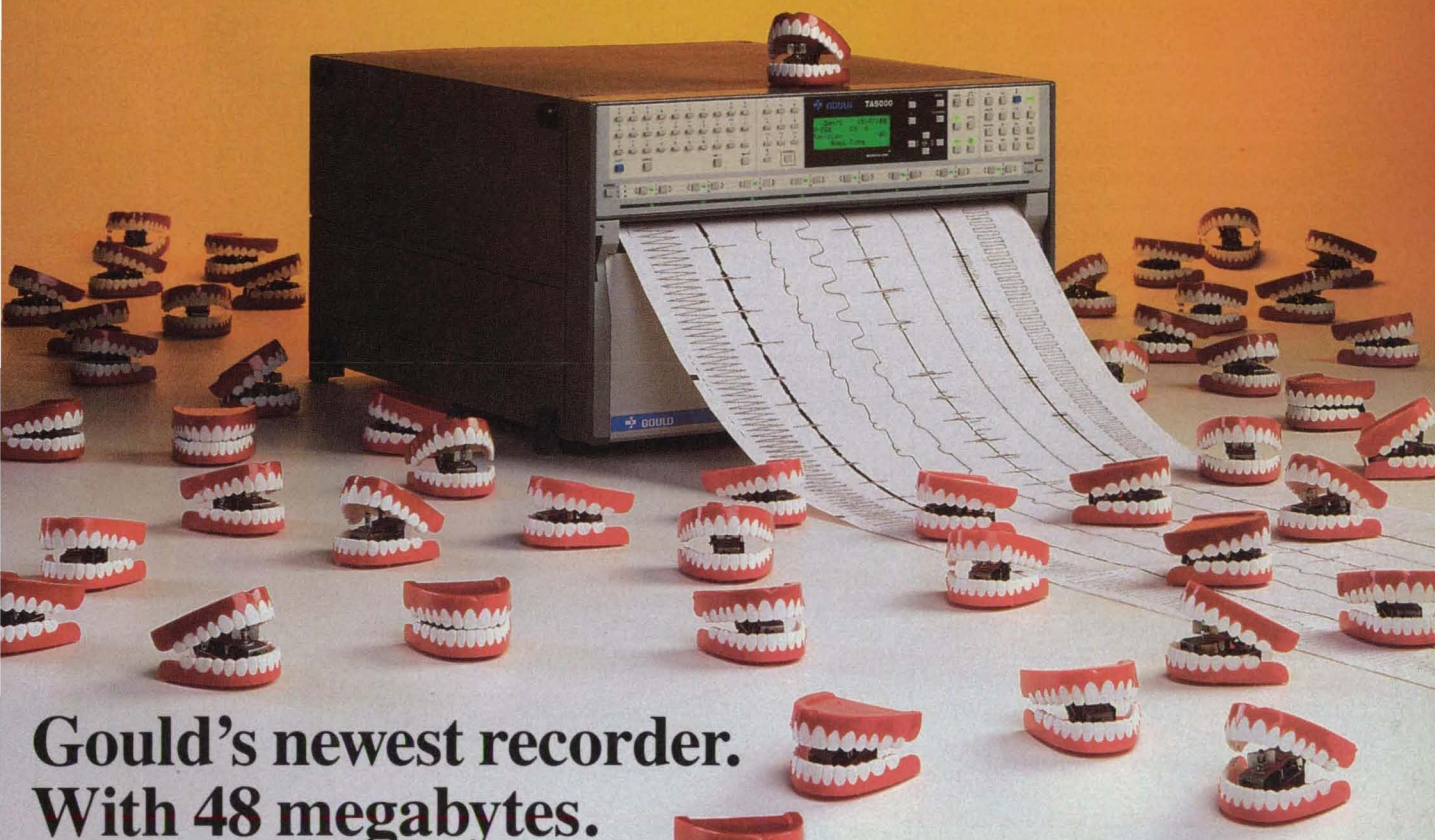

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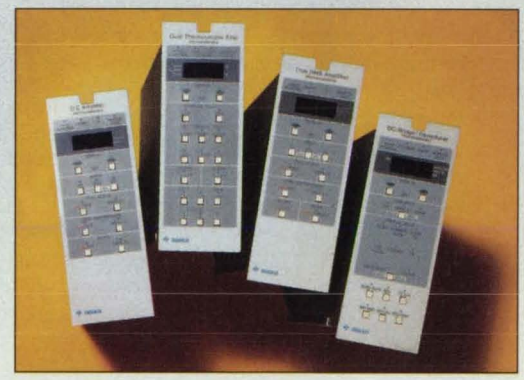

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A fiber-optic sensor monitors the speed and twist of the shaft.

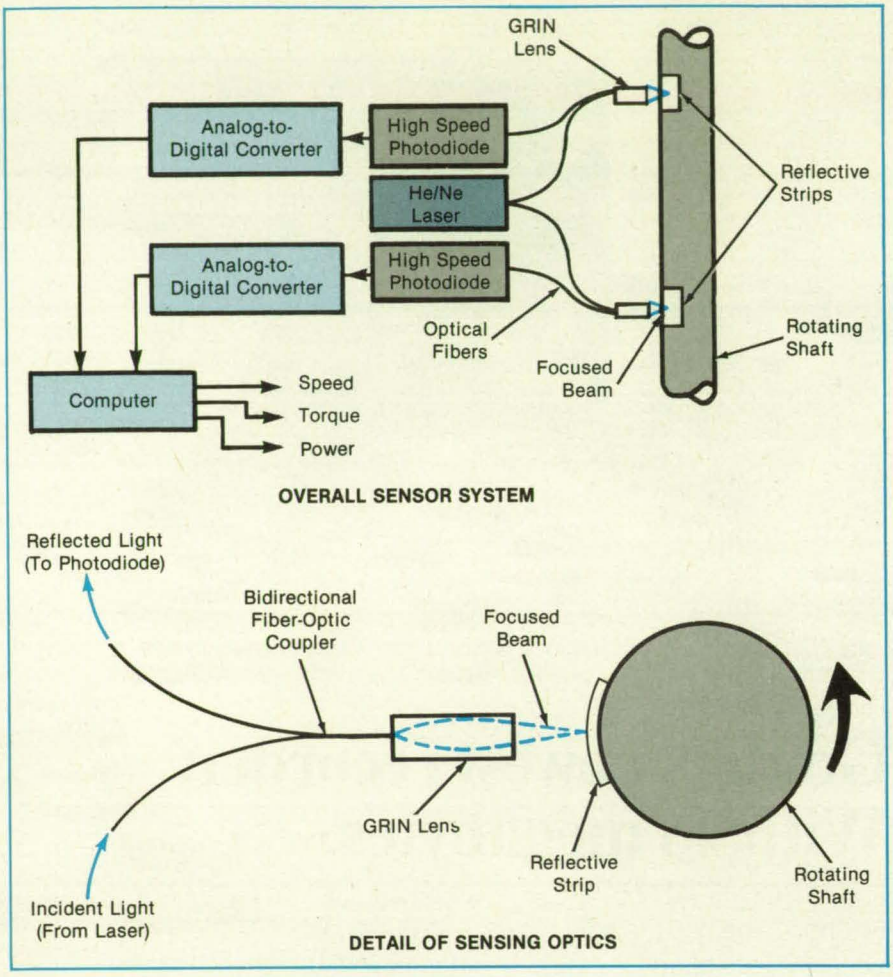
Lewis Research Center, Cleveland, Ohio

A noncontact fiber-optic sensor and associated electronic equipment measure the twist and the speed of rotation of a shaft. From these measurements, a data processor can determine the torque and power. The response of the sensor remains linear even at cryogenic temperatures, unlike the responses of other noncontact sensors based on magnetic, inductive, or capacitive principles. Unlike strain gauges that measure twist, this sensor requires no slip rings or telemetry to transfer signals from the shaft — techniques that are difficult to implement at high speeds and low temperatures. The fiber-optic sensor is therefore well suited for providing data on the performances of turbopumps for such cryogenic fluids as liquid oxygen and liquid hydrogen.

The sensor differs from previous fiber-optic sensors for speed, torque, and power in that its raw outputs are analyzed in groups of data points rather than as a stream of individual data points. By analyzing data in batches, a computer can enhance a signal that has been corrupted by nontransparent impurities in the optical path, by bubbles in the pumped fluid, or by lateral movement of the shaft out of focus of the monitoring optics. One disadvantage of batch analysis, however, is that speed, torque, and power cannot be determined in real time: a small time is needed to collect the specified number of data, transfer them to the computer, and process them.

In the sensor, a beam from a helium/neon laser is directed into a single-strand, multimode optical fiber (see figure). A bidirectional coupler splits the beam into two beams traveling along two fibers. At the ends of each fiber, a gradient-index-of-refraction (GRIN) lens focuses the light onto the shaft. These two sensing tips enable measurement of differential rotation at two points on a line parallel to the axis of the shaft. A reflective surface that covers part of the circumference of the shaft at each sensing tip reflects a pulse of light as it passes through the beam at its location. The reflected light goes back into each fiber through its GRIN lens, and a bidirectional coupler at each such lens transmits the light to a photodiode. The outputs of the photodiodes are digitized and sent to a microprocessor for analysis.

The frequency of the pulses of reflected light represents the speed of rotation. The difference between the times of the pulses from the two reflectors is multiplied by the speed of rotation to obtain the twist. From the twist and the torsional stiffness of the shaft, one can infer the torque. The power equals the torque multiplied by the angular speed of rotation.



Reflective Strips on a rotating shaft reflect two series of light pulses back into the optical system. A bidirectional coupler in each of the two optical fiber paths separates the reflected light from the incident light, sending it to a photodiode for output to an analog-to-digital converter and a computer.

This sensor concept was tested on a phenolic shaft 0.5 in. (12.7 mm) in diameter and 48 in. (1.22 m) long spinning at 1,180 rpm (19.67 Hz). The speed was measured at a sampling rate of 5×10^4 Hz. Angles of twist between 0.005° and 10° were inferred from measurements made at a sampling rate of 2.5 MHz. It was found that increasing the sampling rate of the analog-to-digital converter could improve the measurement resolution and that decreasing the spot size of the focused beam could increase accuracy.

This work was done by George C. Madzsar of **Lewis Research Center**. *Further information may be found in NASA TM-102481 [N90-21360], "A Fiber Optic Sensor for Noncontact Measurement of Shaft Speed, Torque and Power."*

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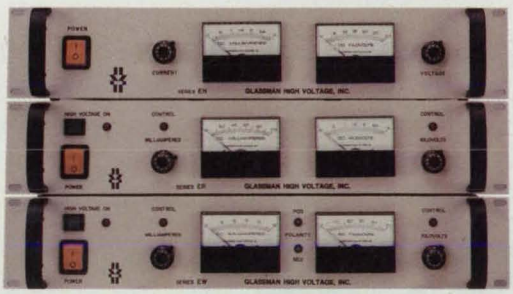

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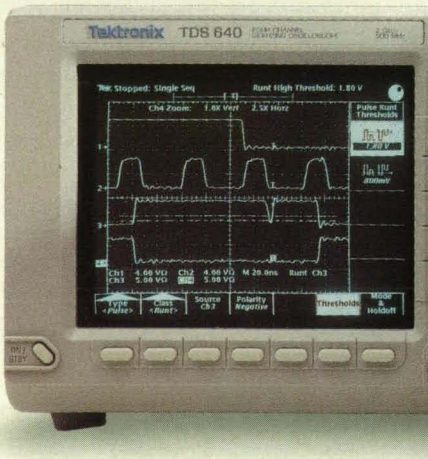

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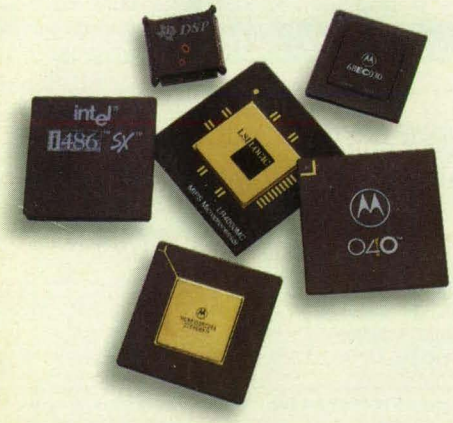

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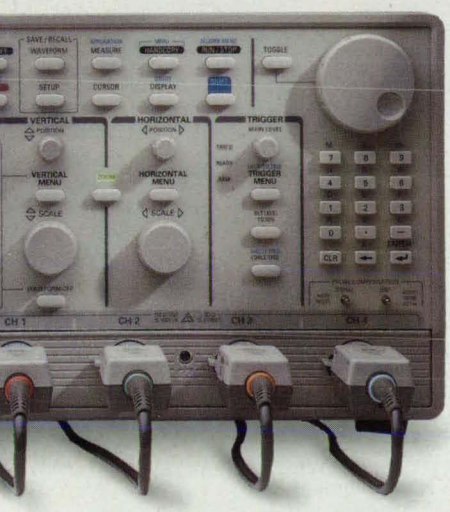

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Pressure-Coupled Acoustic-Transducer Assembly

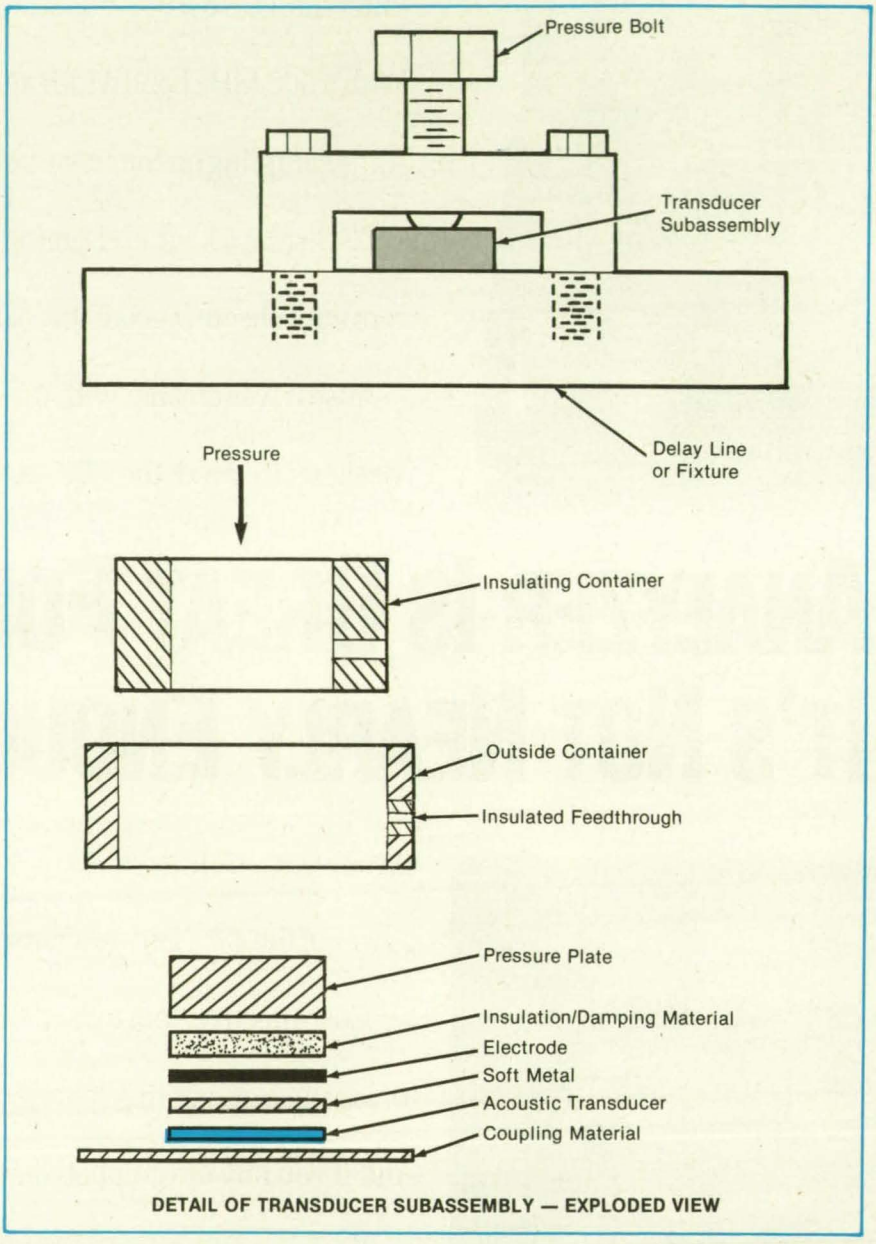
Reliable high-temperature connections can be made and moved from one location to another.

Langley Research Center, Hampton, Virginia

Prior high-temperature measurement systems have typically included acoustic transducers hard-coupled to delay lines by use of epoxies, brazing alloys, indium alloys, ceramics and silicones. The acoustic couplings in such a system involve stationary bonds to the delay line and limit the mobility and use of the transducer assembly. An improved acoustic-transducer assembly developed for use at NASA Langley Research Center is easy to assemble, is relocatable, and can be used at high temperatures.

In the improved assembly, a piezoelectric acoustic transducer is pressure-coupled to a delay line or fixture through a soft metal like aluminum, copper or gold. The transducer subassembly includes a layered structure (see figure) of the coupling material, the transducer, a thin disk of the coupling material that acts as a cushion for the transducer, an electrode disk with a coaxial cable lead attached, insulation/damping material, and a pressure plate.

The fabrication of the transducer subassembly begins with the attachment of the coupling material to one end of a hollow metal cylinder that serves as the outer container of this subassembly. The coupling material can be any soft material that will withstand the operating temperature of the transducer. A cylindrical insulator is placed inside the outer metal container and serves to electrically insulate the transducer and hold the layers of the subassembly in place. Coupling pressure is applied via a rounded bolt threaded through a metal fixture. A coaxial-cable lead is attached to the electrode disk, and the shielding is attached to the metal cylinder so that the cylinder acts as an electrical ground plane as well as an enclosure for the assembly. The acoustic signal can be enhanced by matching the thickness of the coupling material to a quarter wavelength.



DETAIL OF TRANSDUCER SUBASSEMBLY — EXPLODED VIEW

Coupling Pressure Is Applied by tightening the bolt onto the transducer subassembly.

This assembly is designed to be used in the acoustic characterization of materials at high temperatures. It can be used at temperatures up to the melting temperature of the coupling metal. (This melting temperature must be less than the Curie temperature of the transducer.) Because this transducer is not hard-coupled to a delay line, it can be moved easily from one location to another. Also, pressure coupling precludes the problem of matching the coefficients of thermal expansion of the transducer, coupling material, and delay line.

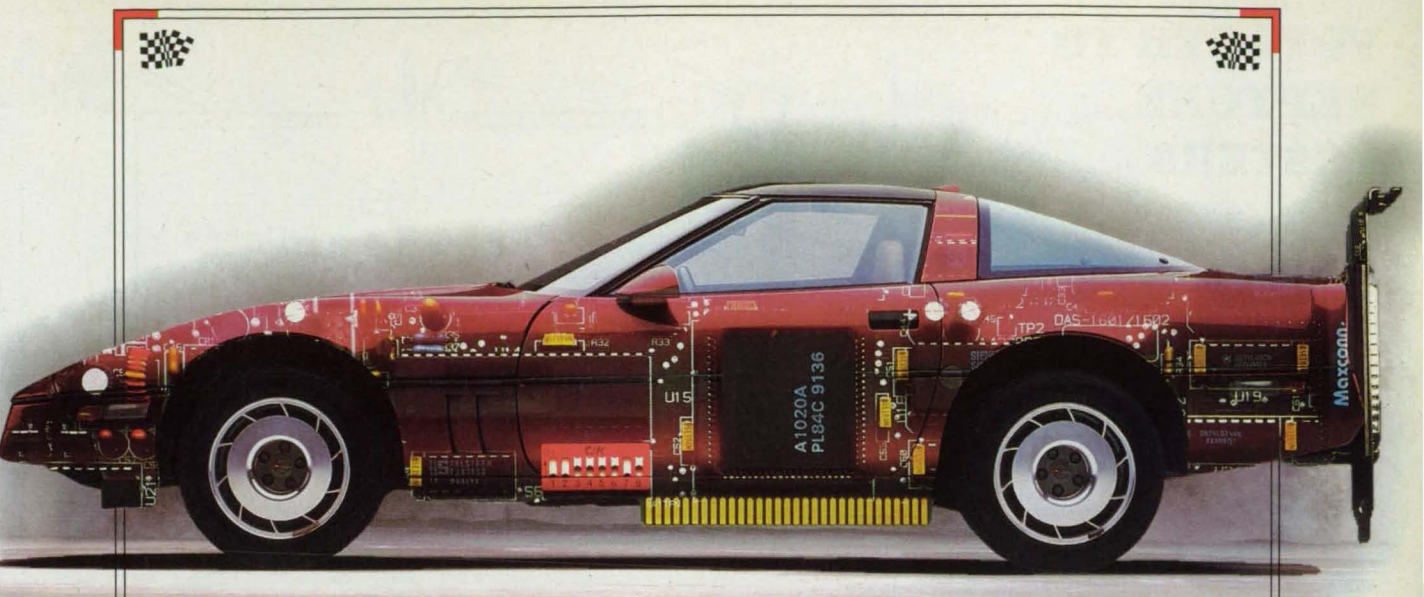
This work was done by F. Raymond Parker of **Langley Research Center**. *No further documentation is available.*
LAR-14283

Measuring Deflections of Propeller and Fan Blades

Bends and twists are deduced from timing of laser-beam shadows.

Lewis Research Center, Cleveland, Ohio

A method based on measurement of interruptions of a laser beam provides information on deflections of the blades of an airplane propeller or an unducted turbofan. The deflections in question are bends and twists caused by centrifugal and aerodynamic loads. The method provides for nonintrusive measurement in a wind tunnel or on an open test stand. Here-



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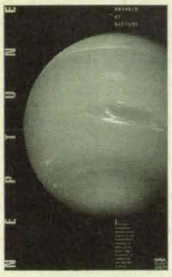
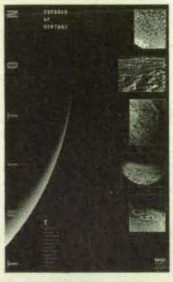
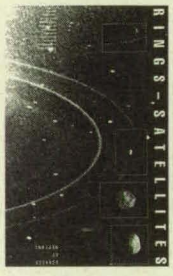


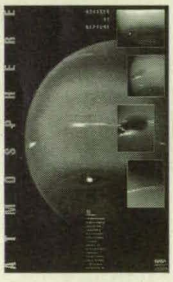
NEPTUNE—Large blue lettering dramatically sets off a photo of Neptune.



TRITON—Eye-catching photos show icy calders and ridges that scar the equatorial terrain. Large lettering is in lavender.



Rings—Satellites is the theme. Large lettering appears in peach.



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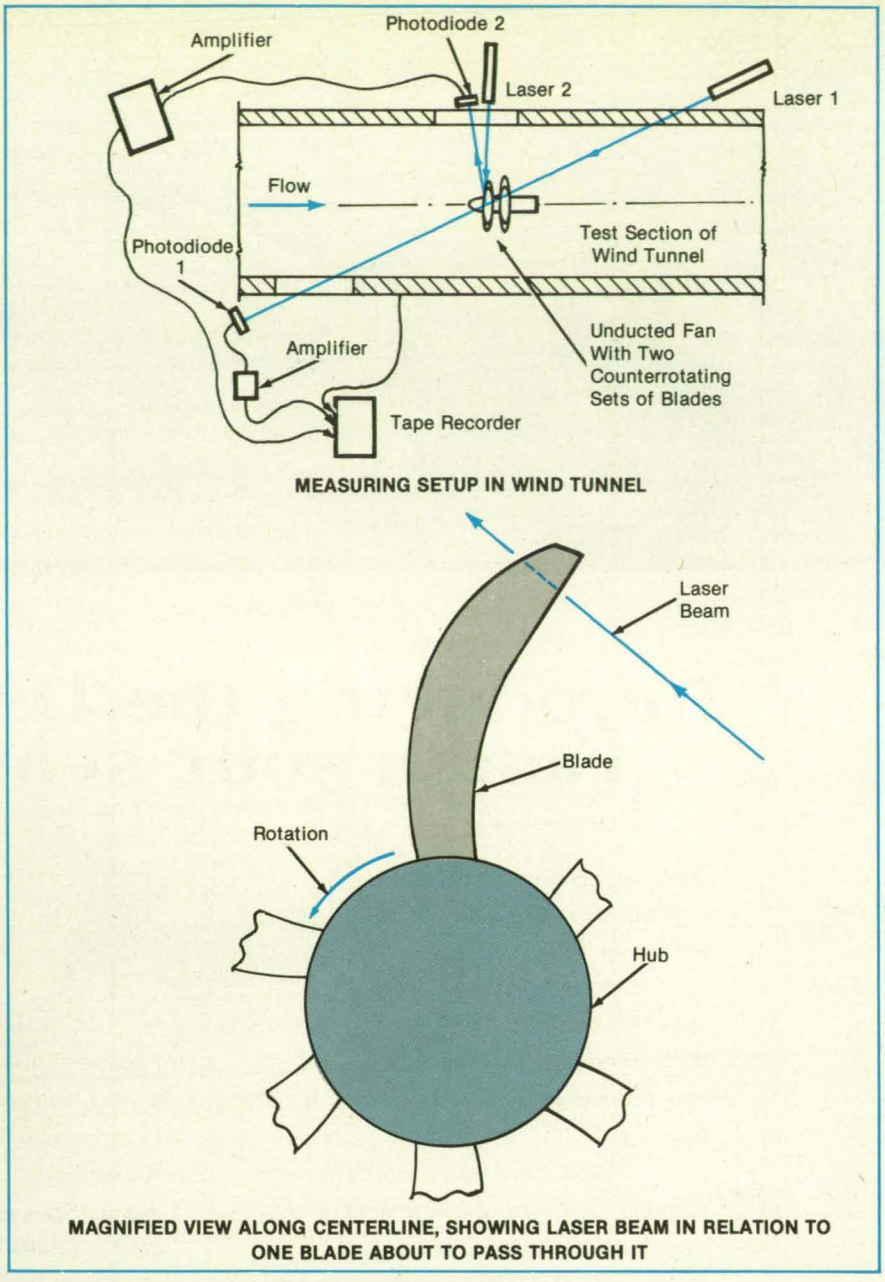

Figure 1. The **Beam From Laser 1** is chopped by the passage of the blades as the propeller or fan rotates. The beam from laser 2 is reflected once per revolution from a mirror on the hub.

tofore, deflections of blades on ducted and unducted rotors have been observed by other optical methods that involve various disadvantages. The present method overcomes the disadvantages and is particularly noteworthy in comparison with methods that rely on the reflectivity of the blades.

In this method (see figure), the beam from a low-power helium/neon laser intersects the plane of rotation near the tip radius, where the deflections are expected to be the largest. Typically, the beam is aimed at an angle of about 10° relative to the pressure surface chord of the blade in a plane nearly perpendicular to the pitch axis.

When the beam is not blocked by a blade, it strikes a photodetector on the wall opposite the wall on which the laser is mounted. Thus, the output of the photodetector is a constant positive voltage except when the blade blocks the beam, when the voltage drops to zero. The leading and trailing edges of these relatively negative pulses correspond to the times of passage of the leading and trailing edges of the blades. In addition to these blade pulses, a once-per-revolution reference pulse is generated by reflecting a second laser beam from a small mirror mounted on the hub.

The pulse data are recorded. On playback, the data are digitized at a reduced speed and processed on a minicomputer to obtain either the steady-state bending and twist deflections or the corresponding vibratory amplitudes. The analysis takes into account the geometry of the laser beam and blades and the relationship between the stationary reference frame and

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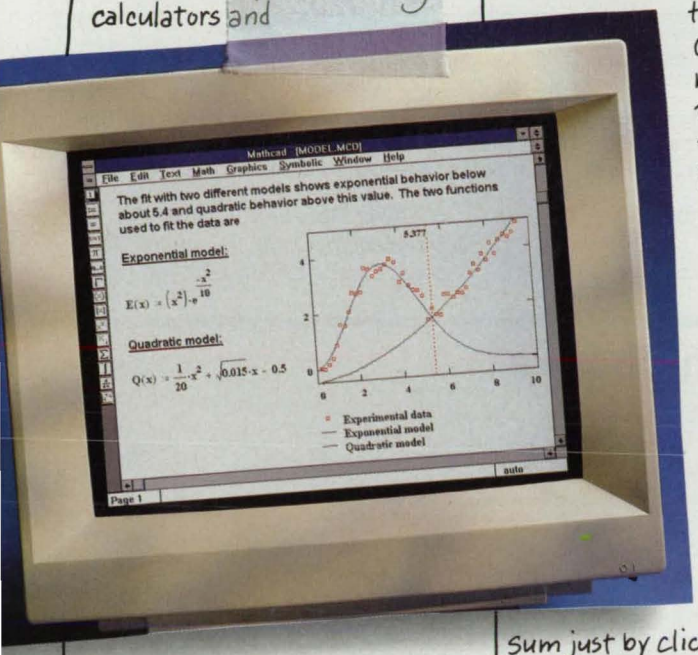

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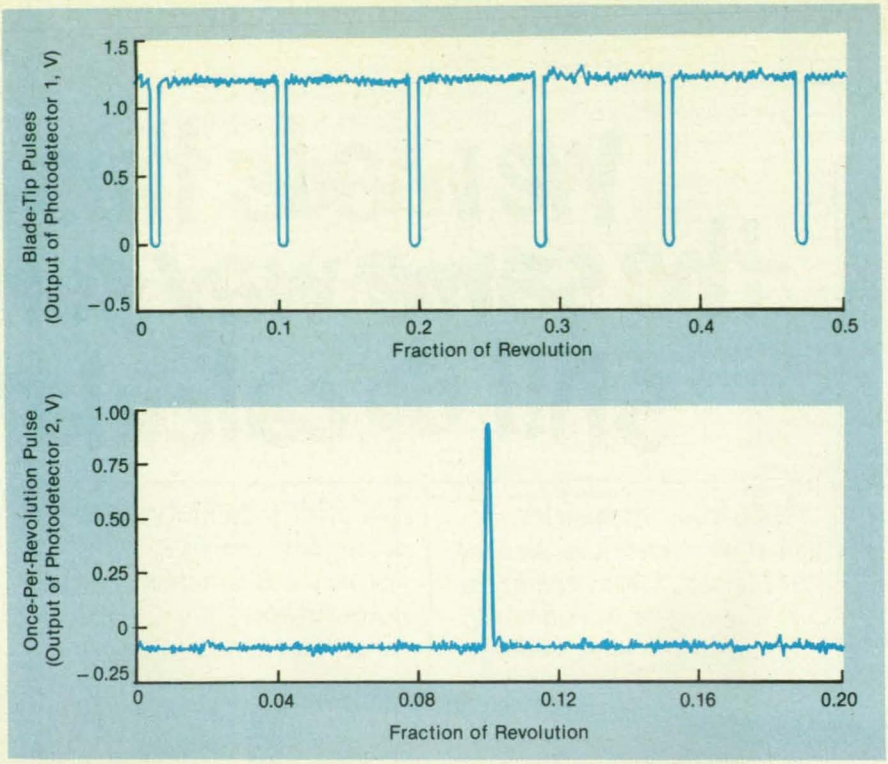


Figure 2. The **Outputs of the Photodetectors** are processed into data on the bending and twisting of the blades. These are measurement traces from a high-speed test of a 0.61-m-diameter rotor equipped with composite-shell blades.

the reference frame that rotates with the hub and blades.

This work was done by Anatole P. Kurkov of **Lewis Research Center**. *For further information, Circle 55 on the TSP Request Card. LEW-15287*

Machine Tests Optical Fibers in Flexure

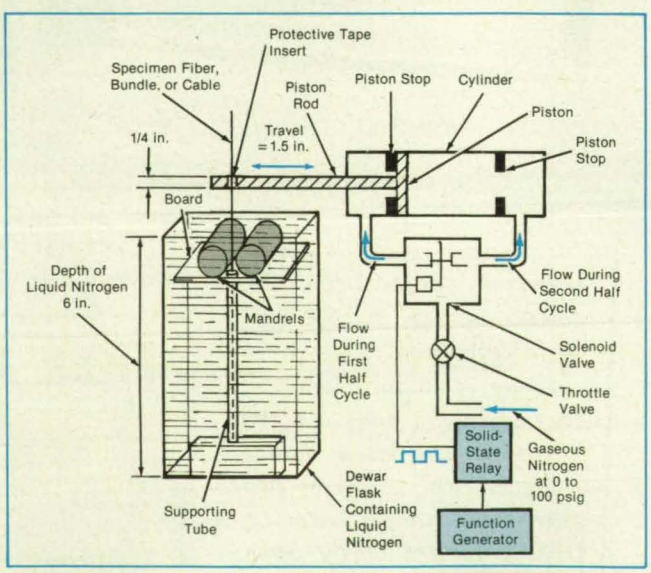
Candidate fibers can be screened inexpensively.

Lewis Research Center, Cleveland, Ohio

A machine repeatedly flexes a single optical fiber or a cable or bundle of optical fibers at low temperature. The machine is inexpensive to build and operate. It tests under repeatable conditions so that candidate fibers, cables, and bundles can be evaluated for general robustness before they are subjected to expensive shock and vibration tests.

The machine bends specimens back and forth over a 45° angle, forcing them around mandrels of ½-in. (12.7-mm) diameter while they are immersed in liquid nitrogen at a temperature of −300 °F (−184 °C). The flexure assembly fits in the top part of a liquid-nitrogen Dewar flask (see figure). The lower end of the specimen is held in a narrow metal supporting tube. The specimen passes between the two mandrels, which are mounted on an epoxy/glass circuit board at the upper end of the supporting tube.

The upper end of the specimen passes through a hole in a piston rod. The temperature at this end is well above that of liquid nitrogen. The piston reciprocates left and right, bending the specimen over the mandrels alternately. Tape compatible with liquid oxygen covers the edges of the hole in the piston rod to protect the specimen from abrasion.



Liquid Nitrogen Surrounds the Specimen as is bent back and forth by the motion of the piston.

A function generator sends electrical pulses, at a rate of about once per second, to a solenoid valve, which admits pressurized nitrogen to the cylinders at opposite sides of the piston in alternation, thus driving the piston back and forth. An electronic counter measures the pulses, and thus the number of cycles. Typically, a specimen is subjected to 10,000 cycles.

This work was done by Hadi Darejeh, Henry Thomas, and Ray Delcher of Rockwell International Corp. for **Lewis Research Center**. *No further documentation is available.*
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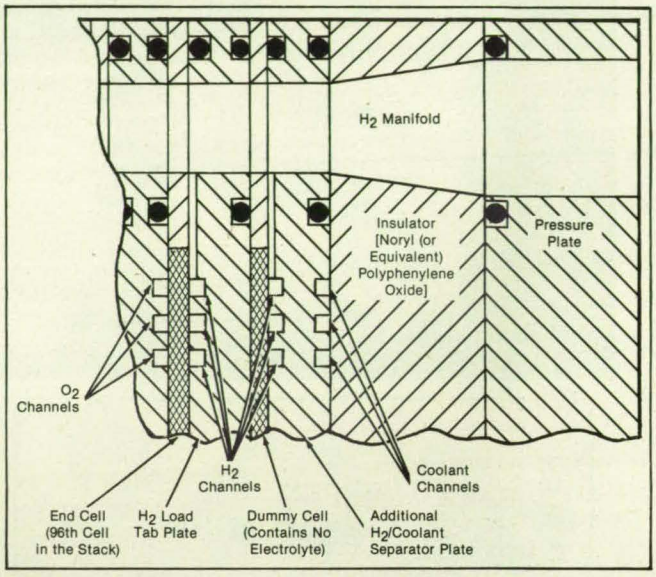
Dummy Cell Would Improve Performance of Fuel-Cell Stack

An inactive cell would reduce the loss of heat and help prevent flooding.

Lyndon B. Johnson Space Center, Houston, Texas

The interposition of a dummy cell between a stack of alkaline fuel cells and the accessory section of a fuel-cell powerplant has been proposed to overcome operational deficiencies that plague the endmost active cell. For example, the voltage drop in the end active cell is usually several millivolts greater than that in other cells. The greater voltage drop signifies that the end cell operates somewhat wetter than the other cells, and this greater wetness is likely the result of a lower operating temperature, which is, in turn, believed to be a result of poor distribution of coolant and incomplete insulation in the end zone. In addition, the active end cell is the cell that is most vulnerable to flooding with water from the accessory section when the stack is tipped during handling. When there is too much water in a cell, the recirculation of hydrogen does not suffice to remove it, and the water can block the flow of hydrogen, so that the cell no longer generates power.

The dummy cell would contain no electrolyte and would be inactive but would otherwise resemble the other cells. The dummy cell, in combination with an additional hydrogen/coolant separator plate (see figure), would ensure that enough heat is retained in the active end cell so that its thermal condition and performance matched those of the interior cells. The additional hydrogen channels in the dummy cell would act as a sump, where condensation entering the stack of fuel cells from the accessory section would be collected before it reached the active cells. The ample heat in the hydrogen/coolant separator plate could evaporate large amounts of collected water. Moreover, the wicklike dummy cell would trap water until it evaporated; this water would not be spilled into the active end cell if the stack were tipped.



The **Dummy Cell** in combination with the additional hydrogen/coolant separator plate would keep the end cell warmer and drier. The end cell is 96th in a stack of fuel cells.

This work was done by G. T. Suljak of International Fuel Cells for **Johnson Space Center**. *No further documentation is available. MSC-21919*

Low-Crosstalk Composite Optical Crosspoint Switches

Performance is enhanced by increasing the number of elementary switches.

John F. Kennedy Space Center, Florida

The term "composite optical switch" denotes an integrated optical waveguide crosspoint switch in a switch matrix of an optical communication system. Each composite optical switch contains two elementary optical switches connected to each other and to optical absorbers in such a way that the crosstalk in one of two states of the switch is substantially less than that of an elementary switch acting alone. The principal advantage of the composite-optical-switch concept is that the crosstalk can be reduced to an acceptably low level at the moderate cost of doubling the number of elementary switches rather than at the greater cost of tightening manufacturing tolerances and exerting more-precise control over operating conditions.

Figure 1 illustrates the two modes or states of operation of an elementary four-port reversing optical switch, which contains an electro-optical switching medium. Depending on the voltage applied to the medium, the switch is in state A or state B. In state A, which is designated the "off" state, the fraction of optical input power leaked between the X and Y channels is ϵ_a; in this state, the signal-to-crosstalk ratio is $(1-\epsilon_a)/\epsilon_a$. In state B, which is designated the "on" state, the fraction of optical input power leaked from the X (or Y) input line to the X (or Y, respectively) output line is ϵ_b, and the signal-to-crosstalk ratio is $(1-\epsilon_b)/\epsilon_b$.

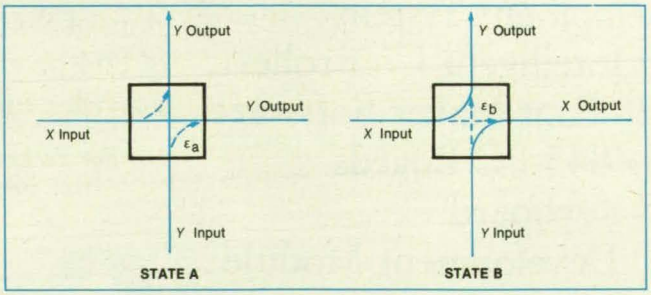


Figure 11. An **Elementary Four-Port Optical Switch** operates in two modes or switching states. Leakage occurs in both states (after Soref and Schissler).

Figure 2 illustrates the operation of the composite switch, in which both elementary switches are simultaneously in either state A or state B. In state A, the leakage between the X and Y channels is only ϵ_a^2, and the signal-to-crosstalk ratio is $(1-\epsilon_a)\epsilon_a^2$. In state B, the leakage is ϵ_b as in an elemen-

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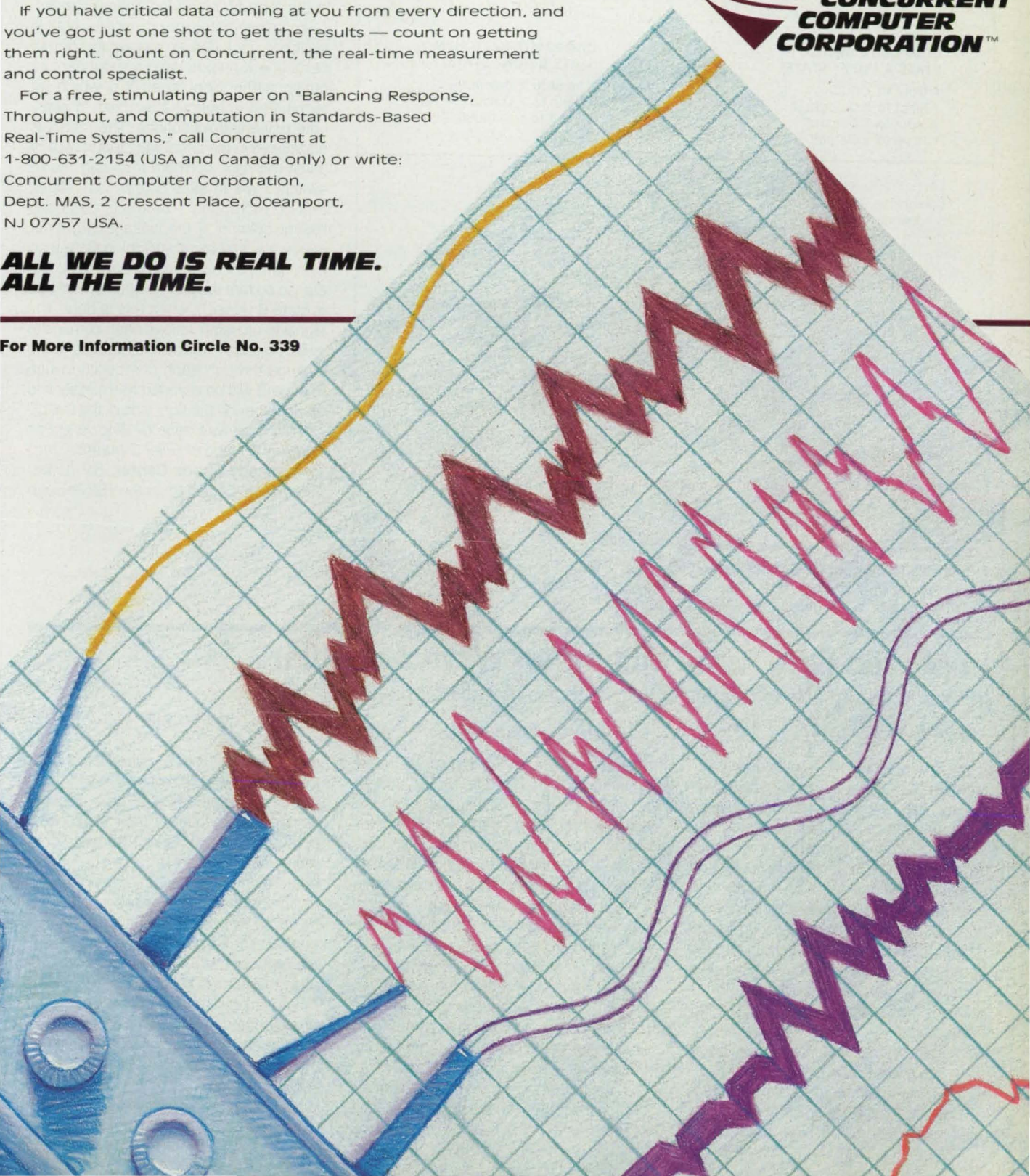


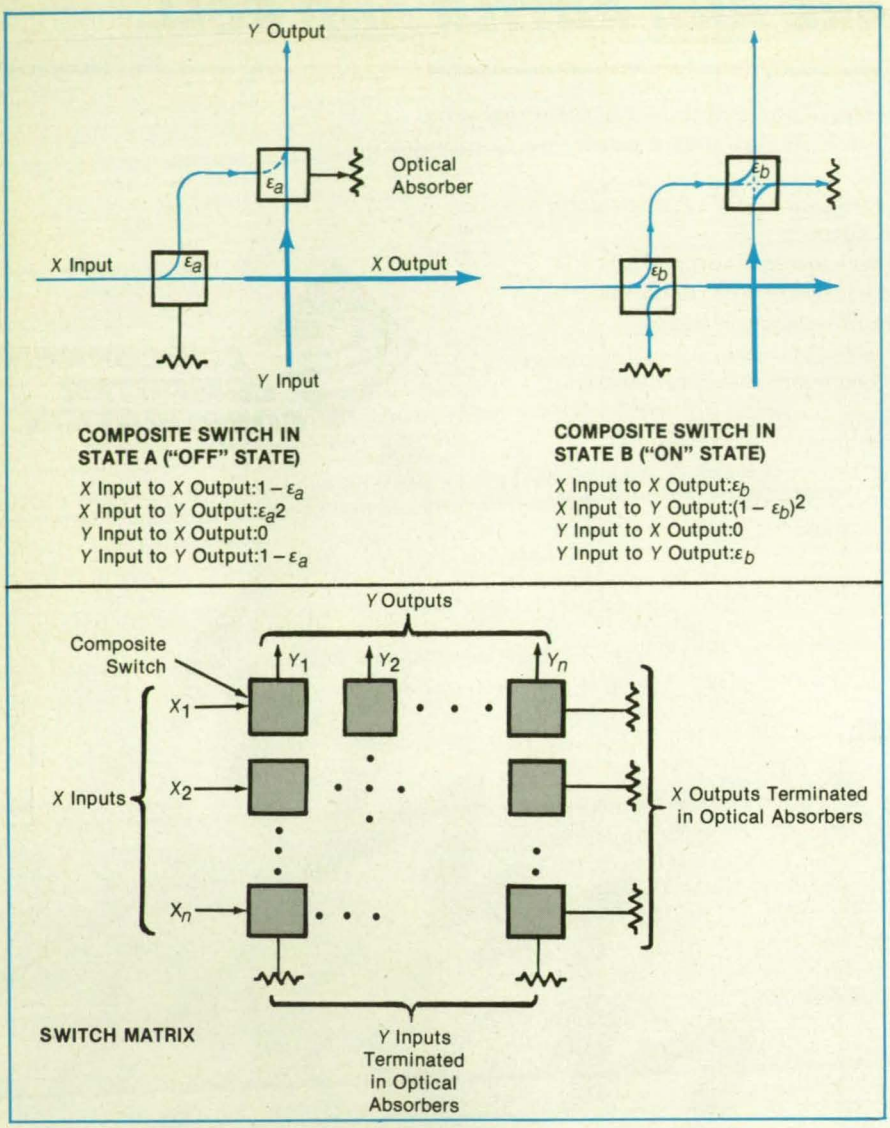


Figure 2. The **Composite Optical Switch** includes two elementary optical switches in tandem, plus optical absorbers. Like elementary optical switches, composite optical switches can be assembled into a switch matrix.

tary switch, and the signal-to-crosstalk ratio is $(1-\epsilon_b)^2/\epsilon_b$. Because ϵ_a and ϵ_b are usually much smaller than 1, the signal-to-crosstalk ratio of a typical composite switch in state A is much greater than that of an elementary switch. The signal-to-crosstalk ratio of a typical composite switch in state B is slightly less than that of an elementary switch, but this does not matter in those applications (e.g., the one described below) in which the *X* output lines are not used. Switch configuration depicted in Figure 2 are feasible and viable, fabricated in the form of integrated optical circuits.

An $n \times n$ matrix of composite optical switches includes n redundant output ports (the *X* outputs) and n redundant input ports (the *Y* inputs), all $2n$ of which are terminated in optical absorbers to eliminate unwanted reflections. The matrix is addressed in the usual way; that is, at any given moment, no more than n of the n^2 switches are in state B (the "on" state), and no more than 1 switch is on in any row or column. If the leakage is greater in one electro-optical switching state than in another, then the matrix should be designed so that the state of greater leakage is state B ($\epsilon_b > \epsilon_a$): when this is done, the signal-to-crosstalk ratio of each composite switch in state A will be minimized, and the leakage through each composite switch in state B will be dumped harmlessly into an absorber on the right side of the matrix.

This work was done by Jing-Jong Pan and Frank Liang of E-Tek Dynamics, Inc., for **Kennedy Space Center**. *For further information, Circle 61 on the TSP Request Card.*

KSC-11405

Improved Grid-Array Millimeter-Wave Amplifier

Input and output are decoupled by virtue of orthogonal polarizations.

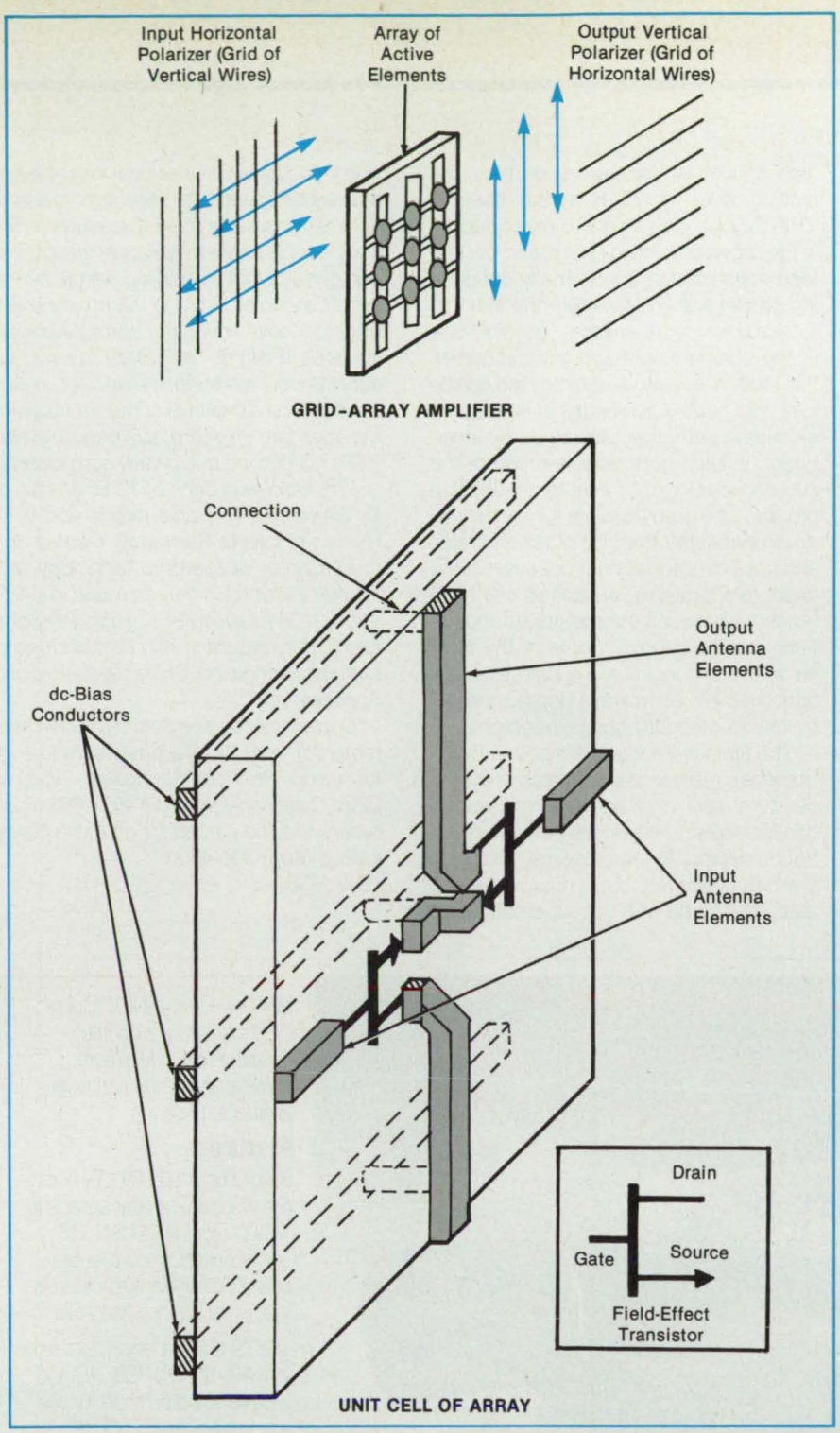
NASA's Jet Propulsion Laboratory, Pasadena, California

Improved grid-array amplifiers that operate at millimeter and submillimeter wavelengths are being developed for use in communications and radar. A grid-array amplifier is a quasi-optical two-dimensional array of gridlike antenna elements and amplifiers that operate in phase lock with each other. Prior grid-array amplifiers were constrained to operate as oscillators because their inputs and outputs shared common polarizations and were therefore coupled, giving rise to feedback and the resulting oscillations. In the improved grid-array amplifiers, feedback is suppressed by making the input polarizations orthogonal to the output polarizations.

A typical improved grid array includes an outer horizontal polarizer (a grid of vertical wires) on the input side, an outer vertical polarizer (a grid of horizontal wires) on the output side, and an array of antenna elements and amplifiers between the two polarizers (see figure). Each unit cell of the array contains two amplifying devices — typically, heterojunction field-effect transistors. The transistors are mounted in a differential configuration, the geometrical and electrical symmetries of which are such as to promote isolation between input and output and to suppress the undesired coupling of radio-frequency power into the dc-bias conductors.

The input horizontal and the output vertical antenna elements are connected to the gate and drain terminals, respectively, of the transistors. To a first-order approximation limited by the small nonlinearities of and differences between the transistors, the instantaneous drain currents of the two transistors differ from the zero-signal dc value by equal (in size) but opposite amounts. Consequently, the instantaneous combined current flowing from the common drain terminal through the circuit board to the bias line at the middle of the unit cell is always nominally the zero-signal dc value. Similarly, the output-antenna terminals at the upper and lower edges of the unit cell carry oppositely varying currents that sum, to first order, to the zero-signal dc value. This first-order cancellation of radio-frequency currents on the dc-bias lines removes some of the geometric constraints on the design of the bias lines and reduces the radio-frequency losses associated with such currents.

Like any amplifier, the grid-array ampli-



The **Grid-Array Amplifier** is a quasi-optical assembly of electronic devices that features polarization-isolated input and output and a differential electrical configuration that suppresses radio-frequency currents on the dc-bias conductors.

fier can be made to oscillate by introducing some feedback. For example, the input polarizer could be replaced by a mirror to reflect horizontally polarized waves back in, and the output polarizer could be tilted slightly from vertical polarization, the amount of tilt being adjusted to adjust the proportion of output power fed back to the input. Several grid-array amplifiers could also be concatenated to form a high-gain beam-amplifying unit; in such a case, each successive stage would be oriented with a polarization orthogonal to that of the preceding and succeeding stages.

This work was done by James J. Rosenberg, David B. Rutledge, R. Peter Smith, and Robert Weikle of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 39 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office – JPL [see page 20]. Refer to NPO-18548.

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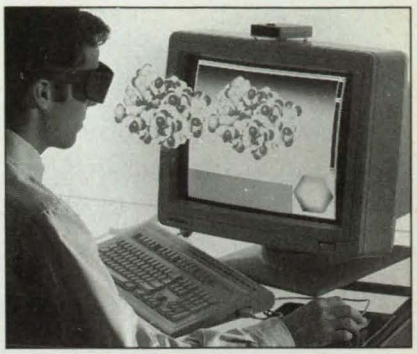

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High-Temperature-Superconductor Films in Microwave Circuits

Fabrication, characterization, and applications are discussed.

A report discusses recent developments in continuing research on the fabrication and characterization of thin films of high-temperature superconducting material and the incorporation of such films into microwave circuits. This work is motivated by the prospect of exploiting superconductivity to reduce electrical losses and thereby enhance the performances of such critical microwave components as ring resonators, filters, transmission lines, phase shifters, and feed lines in phased-array antennas.

The basic problem in fabrication is (1) to deposit a film of the desired high-temperature superconductor (e.g., $YBa_2Cu_3O_7$) on a low-dielectric-constant, low-loss substrate in such a way that the film has a high critical temperature (e.g., near the limiting value of 77 K in the case of $YBa_2Cu_3O_7$), high critical current density in the superconducting phase, and low surface resistance in the normally conducting phase; and (2) to pattern the film into a microwave component — possibly one of the components mentioned above. In this study, the films were deposited epitaxially onto heated substrates of lanthanum aluminate and other dielectrics by laser-beam ablation from targets made of the superconductor. This laser-beam-ablation process was used because it involves lower temperatures than do other chemical and physical deposition processes; at the lower temperatures, undesired chemical reactions between the substrates and the films are suppressed. Some of the films on lanthanum aluminate substrates were patterned into microwave ring resonators by use of standard photolithography.

The films were characterized in terms of surface resistances as functions of temperature, real and complex microwave conductivities, and zero-temperature penetration depths. At temperatures less than the critical temperature, a microwave ring resonator made with the superconductor was found to exhibit electrical losses lower than those of a similar resonator made of gold. On the basis of the measurements, it appears feasible to fabricate microwave components that contain high-temperature-superconductor films. To determine suitability for use in advanced communication systems, it will be necessary to evaluate quantitatively the tradeoffs between superconducting microwave components (with the attendant cryogenic systems) and normally conducting microwave components.

This work was done by K. B. Bhasin, J. D. Warner, R. R. Romanofsky, and V. O. Heinen of **Lewis Research Center** *and C. M. Chorey of Sverdrup Techology, Inc. Further information may be found in NASA TM-103235 [N90-28786], "High Temperature Superconducting Thin Film Microwave Circuits: Fabrication, Characterization, and Applications."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
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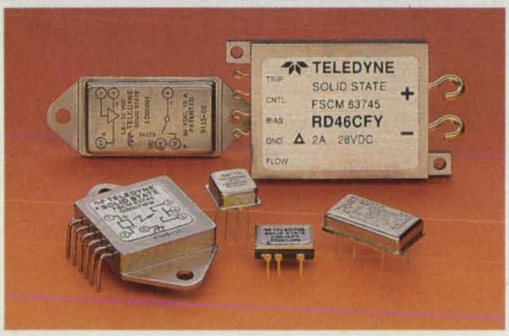

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Robot Avoids Collisions With Obstacles

Infrared sensors detect nearby objects.

John F. Kennedy Space Center, Florida

A developmental robot is equipped with infrared sensors and with a control system that act in concert to enable the manipulator arm to move around obstacles. The robot can avoid collisions with other objects, even when they are moving in unpredictable ways. The control system of the robot requires no prior knowledge of the environment, unlike traditional robot controls, which rely on complete mathematical models of the environment and are at a loss when geometric relationships change or are even partly unknown.

The sensor subsystem includes standard 40-conductor ribbon cable. Forty-pin sockets are attached to the cable at intervals of about 50 mm. An infrared light-emitting diode and a positive/intrinsic/negative photodiode are inserted in each socket. The leads of these diodes are bent so that each makes contact with a different set of conductors in the ribbon. The diodes can thus be addressed and turned on by energizing the appropriate conductors. The ribbon cable is flexible, and can be conformed to any shape object, and placed on the robot where required.

When a light-emitting diode illuminates an obstacle, the reflection is sensed by the collocated photodetector. The control algorithm for the sensor strives to attain two goals: to move the end effector of the manipulator to a target position and to avoid obstacles. The highest priority goes to avoiding collisions; moving the end effector toward the desired position is permitted only when the path is clear.

The algorithm operates in three modes, depending on the proximity of an obstacle:

- Mode 1. The arm moves the end effector toward the target, when no objects are in range, at a standard minimum velocity.
- Mode 2. When an obstacle comes within range, the redundant degree of freedom of the arm is used to avoid hitting the obstacle while continuing to move toward the target.
- Mode 3. If the obstacle comes even closer, all the joints of the arm are moved as necessary to avoid hitting the obstacle, even if this entails moving the end effector away from the target.

This work was done by Edward Cheung, Doug Rosinski, and Dan Wegerif of Merritt Systems, Inc., for **Kennedy Space Center**. *For further information, Circle 84 on the TSP Request Card.*
KSC-11570

Interface for MIL-STD-1553B Data Bus

Advantages include low power, few integrated-circuit chips, and little need for control signals.

Lewis Research Center, Cleveland, Ohio

An electronic control-logic subsystem acts as an interface between a microcontroller and a MIL-STD-1553B data bus (see figure). This subsystem is made of a relatively small number of integrated circuits. It also places very little additional burden on the power supply and on the other data-processing circuitry: it consumes only about 500 mW of power and requires very little control by the microcontroller.

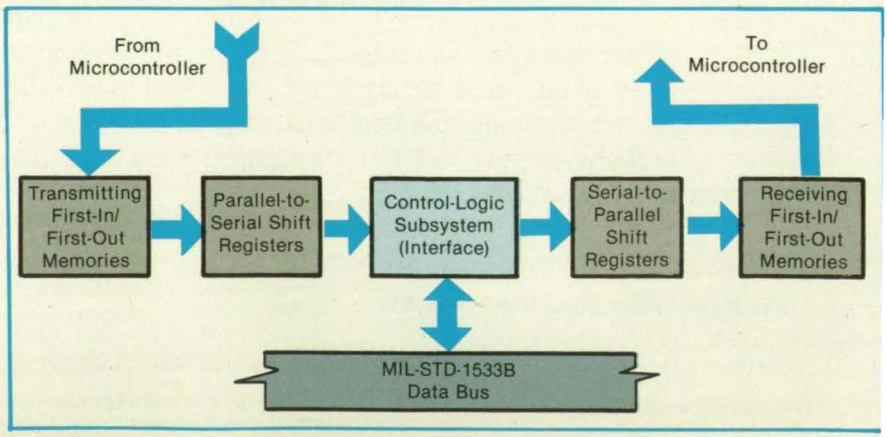
The control-logic subsystem handles the protocols for the MIL-STD-1553B bus, which is a command/response data bus. A bus controller sends commands to remote terminals to request data. Each remote terminal has a unique address and examines each command to determine whether the command contains that address. If it does, then the remote terminal accepts the command and any associated data, then transmits any data that were requested by the command.

The interface decodes each command word, looking for its address and for the number of data words to be received or transmitted. The interface puts the received command and data words into receiving first-in/first-out memories; it obtains data words to be transmitted from transmitting first-in/first-out memories.

The interface-control logic circuit is an HD15530 integrated circuit, which provides Manchester II encoding and decoding of the data and checks parity. Three EP610 programmable logic circuits control the receiving, transmitting, address-matching, and word-counting functions.

The interface operates in a "stand-alone" manner except for a "reset" signal from the microcontroller. In effect, the interface acts like a buffer. It has been used for instrumentation — giving data on voltage, current, and temperature readings. The most recent readings are kept in the first-in/first-out memories and can be sent whenever requested, providing fast response.

This work was done by Bryan L. Davies, Stephen H. Osborn, and Craig C. Sullender of Rockwell International Corp. for **Lewis Research Center**. *For further information, Circle 44 on the TSP Request Card.*
LEW-15038



The **Control-Logic Subsystem** (interface) handles the protocols of a MIL-STD-1553B data bus.

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Voice-Recognition System Records Inspection Data

The inspector can remain visually focused on the workpiece.

Marshall Space Flight Center, Alabama

The Main Injector Voice Activated Record (MIVAR) system acts on vocal commands and processes spoken inspection data into electronic and printed inspection reports. The system was devised to improve the acquisition and recording of data from borescope inspections of the interiors of liquid-oxygen-injecting tubes (called "posts" in the rocket industry) on the main engine of the Space Shuttle. With modifications, the system could also be used in other situations to relieve inspectors of the manual recording of data. The system is particularly advantageous where, as in the original application, it can enhance the flow of work and the quality of the data acquired by enabling the inspector to remain visually focused on the workpiece.

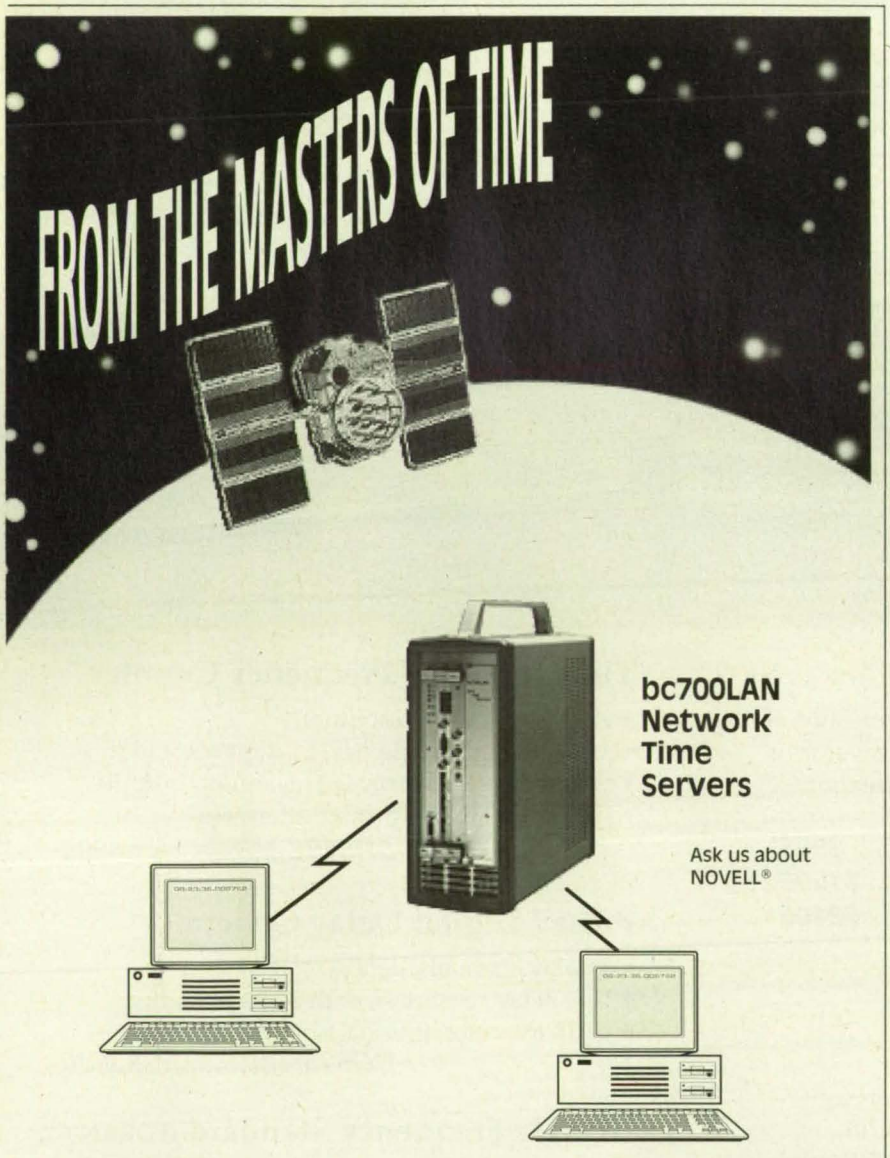
The system includes a personal computer equipped with voice-recognizing, voice-synthesizing, and voice-pattern-memory circuit cards; a microphone to receive vocal input from the inspector; a loudspeaker to issue vocal prompts to the inspector; and the BUG computer program, which governs the acquisition and processing of vocal input. The system also includes another computer that runs the following two programs: (1) The MIVAR program acquires and records inspection data in a structured sequential format specific to the application; MIVAR receives data and sends prompts via BUG. (2) The IDCR program processes the data acquired by MIVAR into a structured report of defects, by category, and prints the report in a prescribed format.

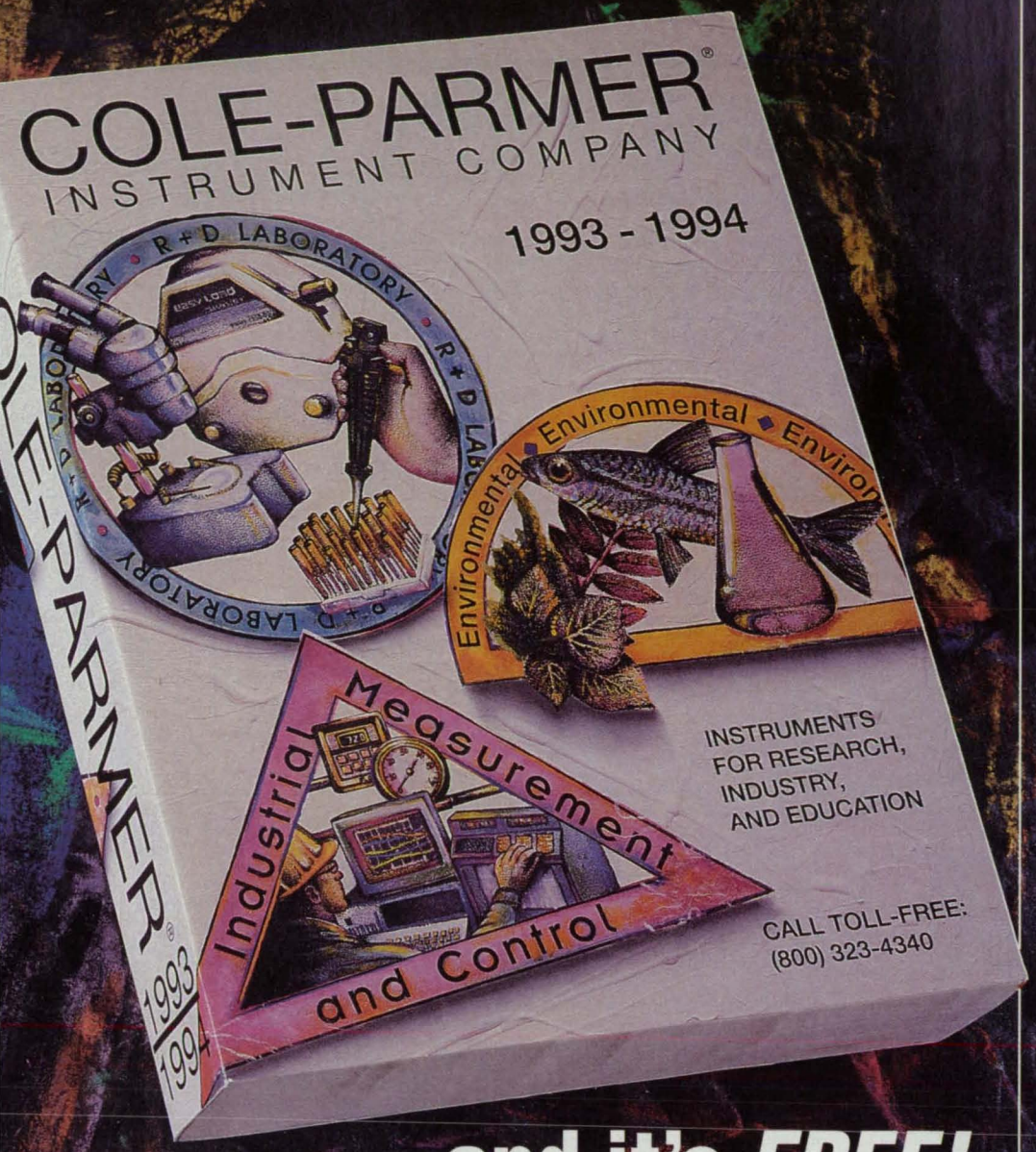
BUG provides for training the system to recognize the vocal patterns of each individual inspector. During a training session, the inspector interacts with the system both vocally and in the conventional manner via a keyboard and video display. BUG prompts the inspector to speak standard commands and standard qualitative and quantitative terms used to describe defects, repeating each several times to establish a range of variations within which recognition can take place. The vocal patterns thus acquired are recorded for subsequent use during inspection. Training is repeated from time to time to update the lexicon to follow subtle changes in the inspector's speech — caused, for example, by changes in health or by changes in rhythm, tone, or volume as a result of experience with the system.

Development of the system continues. One notable deficiency that must be overcome is caused by the physical separation and, therefore, the asynchronism, between the two computers. One of the consequences of this asynchronism is that when BUG misrecognizes a word or phrase, incorrect data can be recorded. In the short term, the inspector can minimize the number of incorrect data by adhering strictly to the error-detection procedures in the instruction manual of the system.

This work was done by Larry L. Rochester of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 2 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29780.





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Demonstration AOTF Imaging Spectrometer

Spectral images of high quality have been obtained.

NASA's Jet Propulsion Laboratory, Pasadena, California

Figure 1 is a schematic diagram of a "breadboard" acousto-optical-tunable-filter (AOTF) imaging spectrometer. As the name suggests, this is an optical system in which an AOTF serves as a spectrally dispersive element that causes the image on the final focal plane to be shifted on that plane by a distance that depends on the wavelength of light emanating from the scene. AOTF imaging spectrometers are expected to prove useful in several applications that involve the identification, via characteristic spectra, of substances in the observed scenes: examples include prospecting for minerals and detecting chemical pollutants.

Light from the scene enters the system through a camera zoom lens, which forms a real image on a first image plane. The light from the real image passes through a TeO_2 AOTF to a relay lens, which forms a virtual image that is viewed by a charge-coupled-device (CCD) video camera equipped with a zoom lens.

Acoustic waves driven by a radio-frequency generator give rise to an index-of-refraction grating in the AOTF. The frequency of the driving signal can be varied to vary the spatial period of the grating, thereby varying the angle of diffraction of each spectral component of the light traveling toward the relay lens.

In this case, the system is configured so that in the wavelength range of interest, only light from first-order diffraction of the ordinary beam in the TeO_2 medium contributes to the virtual image viewed by the camera. As the AOTF is scanned in wavelength and the angle of diffraction changes, the virtual image viewed by the camera shifts laterally. The operations of the radio-frequency generator and camera are controlled by a personal computer, which also processes, stores, and controls the display of spectral image data.

The upper part of Figure 2 shows results of a demonstration in which the system was aimed at a synthetic ruby on a light-green paper illuminated by a sunlamp. This is a mosaic of images made in spectral bands centered at wavelengths from 750 nm to 500 nm. The spectral images show that the ruby fluoresces in the deep red with a peak at 694 nm and absorbs strongly in the blue-green region. The background paper lights up in the blue-green region, as one would expect.

This work was done by Tien-Hsin Chao, Jeffrey Yu, and Li-Jen Cheng of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 48 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-18410.

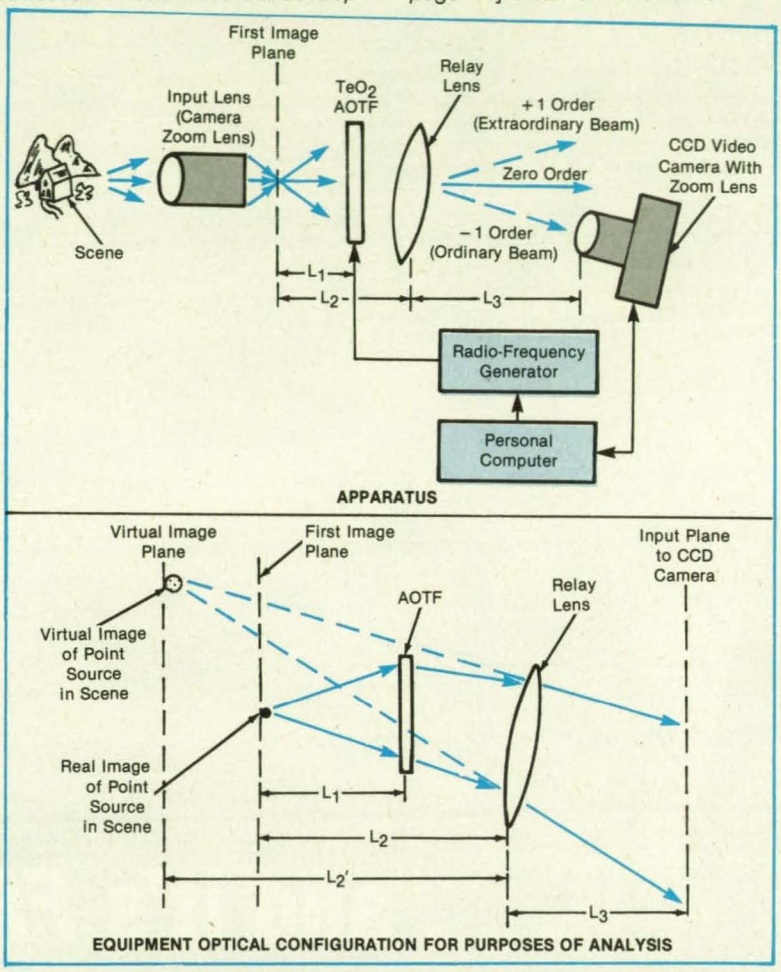

Figure 1. The **Camera Views a Virtual Image** formed in diffracted light. The angle of diffraction (and, therefore, the apparent lateral position of the virtual image) depends on the wavelength of the light.

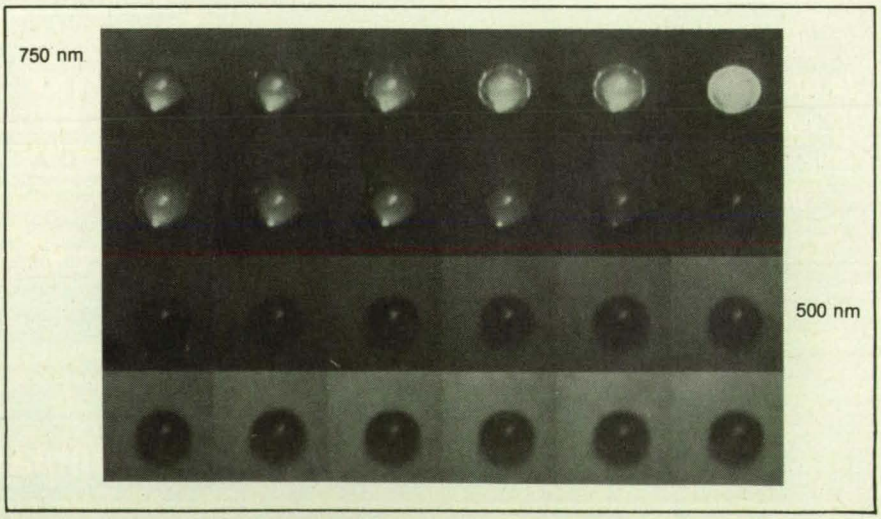

Figure 2. **Each Image** in this mosaic shows a synthetic ruby on a green background in 1 of 24 spectral bands. Wavelengths decrease in sequence along each column from top to bottom, then from left to right in going from column to column.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Differential Interferometry for Spacecraft Navigation

Accurate angular-measurement technique can help navigate future Mars missions.

In an extension of Earth-based differential navigation techniques (e.g., GPS and LORAN) to the challenge of interplanetary spacecraft navigation, a report proposes the use of differential very-long-baseline interferometry (ΔVLBI) to measure very accurately the angular separation, as viewed from Earth, of two spacecraft near another planet. One of the spacecraft would be in orbit around the planet on a trajectory that had already been determined accurately, relative to the planet, by conventional Doppler tracking. The other spacecraft would be approaching the planet. The idea is to use the ΔVLBI "tie" between the two spacecraft and the previously determined "tie" between the orbiter and the planet to increase the accuracy of navigation of the approaching spacecraft relative to the planet.

Each spacecraft would transmit microwave signals at two different frequencies, called "VLBI tones." Two widely separated ground stations would aim their antennas alternately at one spacecraft, then at the other during integration periods typically a few minutes long. During each integration period, the stations would track phases of the two signals from one of the spacecraft by use of a closed-loop digital tracking receiver.

A quantity called the "one-way range observable," τ_{ij}, would be computed from the observation of spacecraft j by station i:

$$\tau_{ij} = \frac{\phi_{ij}(\nu_{j1}) - \phi_{ij}(\nu_{j2})}{\nu_{j1} - \nu_{j2}}$$

where ν_{j1} and ν_{j2} are the frequencies of the two VLBI tones of spacecraft j. By differencing between stations, one would obtain the interferometer delay, or differenced one-way range, for spacecraft j:

$$\tau_j = \tau_{1j} - \tau_{2j}$$

The final "observable" quantity, τ, would be computed by taking the difference between the differenced one-way range observables of the two spacecraft:

$$\tau = \tau_A - \tau_B$$

This double-differenced range observable would provide a sensitive measure of the relative angular position of the approaching spacecraft relative to the orbiter:

$$\tau = \frac{1}{c}\mathbf{B}\cdot(\hat{\mathbf{S}}_A - \hat{\mathbf{S}}_B)$$

where **B** is the baseline vector between the ground stations, c is the speed of light, and $\hat{\mathbf{S}}_A$ and $\hat{\mathbf{S}}_B$ are the unit vectors in the directions of the approaching and orbiting spacecraft, respectively. The final angular accuracy would thus be directly related to the total error in the ΔVLBI delay.

One significant advantage of the second subtraction is that it would cancel some ΔVLBI errors that are common to both spacecraft observables; these errors increase or decrease along with the angular separation between the spacecraft. Thus, the most accurate differential angular tracking would be obtained when it is most needed — when the spacecraft are close.

Preliminary calculations have been performed for a pair of spacecraft near Mars with VLBI tones at about 8.4 GHz separated by 40 MHz or VLBI tones at about 32 GHz separated by 400 MHz. If the spacecraft are observed on a 5-minute cycle with an integration time of 2 minutes on each spacecraft and 1 minute allowed for sluing the antennas between spacecraft, then at angular separations of a few degrees, the accuracy of the ΔVLBI measurement of the angular separation should be of the order of a few nanoradians. Such a capability could help to enable future missions to Mars, incorporating ambitious aerobraking maneuvers to achieve orbit insertion.

This work was done by Charles D. Edwards, James S. Border, William M. Folkner, and Lincoln J. Wood of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Spacecraft-Spacecraft Very Long Baseline Interferometry For Planetary Approach Navigation," Circle 70 on the TSP Request Card. NPO-18417*

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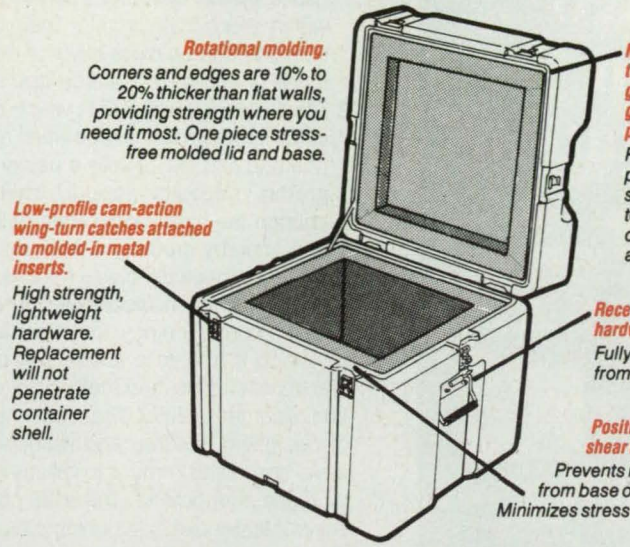

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For More Information Circle No. 478

Effects of Environmental Electrical Charges on Spacecraft

A handbook addresses surface and internal charging and discharging, single-event upsets, and related design issues.

A handbook presents information on three kinds of disruptive effects of environmental electrical charges upon the operations of electronic circuits and other sensitive equipment in spacecraft. These three effects are the following:

1. Electrostatic surface discharge, which occurs when differential charge accumulated on adjacent surface areas becomes sufficient to cause dielectric breakdown between those areas. The charge comes from the plasma of outer space and/or photoemission caused by ultraviolet radi-

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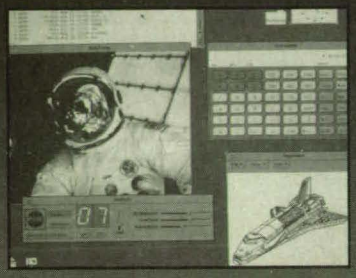

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For More Information Circle No. 469

ation from the Sun.

2. Internal discharge, which occurs when radiation penetrates the spacecraft and causes differential charging of interior points up to the breakdown level. Because internal discharges can take place within electronic circuits, their consequences can be more adverse than are those of equivalent surface discharges.
3. Single-event upset (SEU), which occurs in a microelectronic circuit when a single charged particle, usually a heavy ion or proton, deposits enough charge to change the binary logic state of the circuit, thereby creating a false datum.

The handbook devotes a full chapter to each phenomenon, discussing its environmental source, the physical mechanisms by which it affects a spacecraft and its electronic circuits, and methods of prediction. Another chapter discusses methods of designing, testing, and monitoring to make spacecraft immune to failures caused by these phenomena. The book contains several appendixes, including a bibliography, glossary, list of computer codes, and list of sensors and detectors for monitoring charged particles and discharges.

This work was done by Paul A. Robinson, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Spacecraft Environmental Anomalies Handbook," Circle 81 on the TSP Request Card.*
NPO-18350

More About Laser Scanner Tests for Single-Event Upsets

Laser-scan and heavy-ion data are found to be correlated within a factor of two.

Two reports describe preliminary theoretical and experimental studies based on the method described in "Laser Scanner Tests for Single-Event Upsets" (NPO-18216), *NASA Tech Briefs*, Vol. 16, No. 2 (February 1992), page 36. To recapitulate from the noted prior article: The laser-scanning method of testing for single-event upsets is intended to overcome the disadvantages of, complement, and/or substitute for the more-expensive cyclotron-testing method, which does not provide spatial resolution. In the laser-scanning method, picosecond pulses of light from a dye laser are focused at selected locations of the electronic device under test to determine the spatial dependence of its vulnerability to single-event upsets. The wavelength of the beam can be adjusted to any of a number of values above or below the gap between the valence and conduction electron-energy bands of the semiconductor device material to vary the effective depth of penetration into the device. Thus, the laser-scanning method provides data that are spatially resolved in all three dimensions.

The device tested in the experiments was a commercial 256K n-channel metal oxide/semiconductor dynamic random-access memory, each memory cell of which consisted of an access transistor and a storage capacitor. Each memory cell occupied an area of about 50 μm^2, and the area of the laser spot on the surface of the device was about 1.8 μm^2. In some tests, the cells were initially in the "one" (charged) logic state, in which they are most sensitive to single-event upsets; in other tests, they were initially in the relatively insensitive "zero" (discharged) state. Bit maps of the upsets in affected memory cells were made at various wavelengths, pulse energies, and bias voltages applied to the sensing amplifiers through which the contents of the memory cells are read out. Bit maps made from the data showed the bit errors in cells in the vicinity of the laser spot.

According to the applicable theory of single-event upsets, an upset (the flip of a memory cell to the opposite logic state) occurs when the incident laser pulse or energetic ion excites a sufficient number of charge carriers that the charge collected at the affected junction of the device exceeds a critical value. In these studies, diffusion was regarded as the predominant physical mechanism for the transport of charge from the ion track or laser beam to the affected junction or junctions. A mathematical model of the bit-error response of the device, based on the theory of diffusion, was calibrated by the multiple-bit-error laser-scan data and the result compared with data on bit errors produced by exposure to energetic heavy ions. The two sets of data were found to agree within a factor of two.

This work was done by Quiesup Kim, Larry D. Edmonds, and John A. Zoutendyk of Caltech and Harvey R. Schwartz of Trend Western for **NASA's Jet Propulsion Laboratory**. *To obtain copies of the reports, "A Study of Multiple-Bit Errors in an NMOS DRAM by a Picosecond Pulsed Dye Laser" and "Diagnosis of NMOS DRAM Functional Performance as Affected by a Picosecond Dye Laser," Circle 82 on the TSP Request Card.*
NPO-18494

Telemetry Tests of the Advanced Receiver II

Performance was at least as good as that of two other receiving subsystems.

A report describes telemetry tests of the Advanced Receiver II (ARX-II) — a digital radio receiving subsystem that operates on the intermediate-frequency output of another receiving subsystem called the "multimission receiver" (MMR), that detects

carrier, subcarrier, and data-symbol signals transmitted by spacecraft, and that extracts Doppler information from the signals. The tests were performed in a laboratory called "Compatibility Test Area 21," using signals supplied by a test apparatus called the "telemetry simulator assembly" (TSA).

To obtain data for comparison, the MMR and ARX-II were tested simultaneously and in parallel with two different receiving systems: (1) a receiver of another type called "Block III" (Blk-III) followed by a baseband processor assembly (BPA) and (2) the Block-III receiver followed by a subcarrier-demodulation assembly (SDA) and a symbol-synchronization assembly (SSA).

The signal produced by the TSA and associated equipment was a 2,295-MHz carrier modulated by a square-wave subcarrier that was, in turn, phase-modulated with a pseudorandom sequence that imitated a stream of telemetry bits. The symbol signal-to-noise ratio (SSNR) and the symbol-error rate (SER) of each receiving system were measured. The decoded outputs of all three receivers were sent to a computer for processing into bit-error rates. The foregoing measures of performance of the three systems were mapped into an equivalent common measure called the "equivalent symbol signal-to-noise ratio" (SERSNR) to enable comparisons.

Data were accumulated at bit rates from 16 s^{-1} (typical of the Pioneer spacecraft) to 268.8 ks^{-1} (typical of the high-rate data channel of the Magellan spacecraft). Analysis of the data showed that the performance of the MMR/ARX-II system was comparable and sometimes superior to the performances of the Blk-III/BPA and Blk-III/SDA/SSA systems.

This work was done by Sami M. Hinedi, Roland P. Bevan, and Miguel Marina of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "The Advanced Receiver II Telemetry Test Results in CTA-21," Circle 12 on the TSP Request Card.*
NPO-18459

Development of Infrared Imager for Spacelab

A terrestrial instrument is modified for use in outer space.

A report discusses progress in the development of an infrared-imaging instrument for use in microgravity scientific experiments in a manned module in the payload bay of the Space Shuttle. This imager is intended primarily for the characterization of surface temperatures in a microgravity fluid-physics experiment. The design of the imager was to be as versatile as possible so that the instrument could serve as an "off-the-shelf" unit for other experiments, eliminating the need to duplicate development and qualifications for spaceflight for future experiments.

Because a limit on overall development time (15 months) was the major consideration, the development team chose existing technology to eliminate uncertain development work. It was decided to modify a commercial (Inframetrics™ Model 600) scanning infrared radiometer to satisfy the requirements of the experiment and of spaceflight while maintaining the basic performance characteristics of the commercial instrument.

Some of the modifications were necessitated by the environment during launch and orbit, while others were specific to the experiment. Because of the vibrations that occur during launch, a more-rugged military scanning mechanism was used in place of the standard scanning galvanometers of the original instrument. A liquid-nitrogen Dewar that cools the detector in the original instrument was replaced by small, lower-power, closed-Stirling-cycle cooler. A 7-bit analog-to-digital converter was replaced by an 8-bit converter to increase the dynamic range. Where possible, the electronic components on each printed-circuit board were replaced with MIL-STD electronic components; this change required modifications of the patterns of three of the five printed-circuit boards. Components for which there were no MIL-STD equivalents were replaced by equivalent screened, derated commercial components of higher quality.

The method of mounting the printed-circuit boards was changed to facilitate the dissipation of heat and to increase the tolerance of vibration. Because the power consumed by the electronics was low, active cooling was not necessary. The external structures of the instrument were pressurized and sealed to contain any toxic gases that might emanate from the enclosed materials. A microprocessor was added to the experiment-controlling computer (which is in an enclosure separate from that of the imager) to perform several functions related to automatic gain control, including selection of the temperature range. The spectral passband was tailored by selectively coating windows in the optical path.

This work was done by Alexander D. Pline and Robert L. Butcher of **Lewis Research Center**, *and Michael Conneley of Barnes Engineering Division of EDO Corporation. Further information may be found in NASA TM-102503 [N90-18752], "Spacelab Qualified Infrared Imager for Microgravity Science Experiments."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
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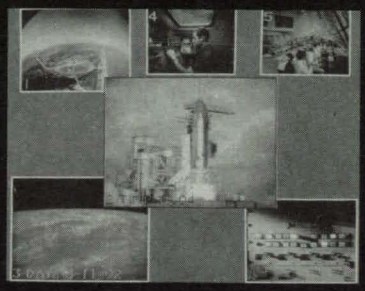

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For More Information Circle No. 479

Mapping Temperatures on Heat Pipes

Paints containing thermochromic liquid crystals make isotherms visible.

John F. Kennedy Space Center, Florida

Paints containing thermochromic liquid crystals (TLC's) can be used to map the temperatures on (and thereby assess the thermal performances of) heat pipes and thermosyphons. The color of a thermally sensitive TLC coat changes reversibly upon heating or cooling. Each distinct color indicates a particular temperature. Thus, transient and steady-state isotherms become visible as colored bands. The positions and movements of the bands yield information about startup transients, steady-state operation, cooler regions containing noncondensible gas, and other phenomena relevant to the performance of a heat pipe.

To prepare for a demonstration of this concept, copper heat pipes 15 mm in diameter and 730 mm long with annular copper mesh wicks were fabricated and charged to a working-mass quality of about 70 percent with refrigerant 12 (dichlorodifluoromethane). The outsides of the heat pipes were coated with a slurry of microencapsulated TLC's. The condenser end of each heat pipe was fitted with a Bourdon-tube pressure gauge and a filling-and-venting valve line as shown in Figure 1.

In a typical experiment conducted as part of the demonstration, the evaporator end of a heat pipe was immersed in an insulated hot-water bath. The rate of transport of heat by the pipe could be quantified by a simple enthalpy balance. Heat was removed from the pipe at the condenser end by free or forced convection of air, or the pipe could be fitted with a water-cooled jacket. Figure 2 represents the distributions of temperature and color along a heat pipe under typical steady-state demonstration conditions.

The heat-transfer behavior of a simple heat pipe of the type just described was compared with that of a solid copper rod that was also coated with TLC's. The lower ends of both were simultaneously placed in hot water baths, and the thermal behaviors visually observed. Immediately upon immersion, a rainbow-colored band began to migrate up the rod, at an initial rate of about 5 mm/s. Approximately 10 s later, when the thermal front had moved only a few centimeters up the rod, the colors of the entire adiabatic and condenser regions of the heat pipe changed quickly, indicating the quick heating of these regions to more nearly isothermal conditions.

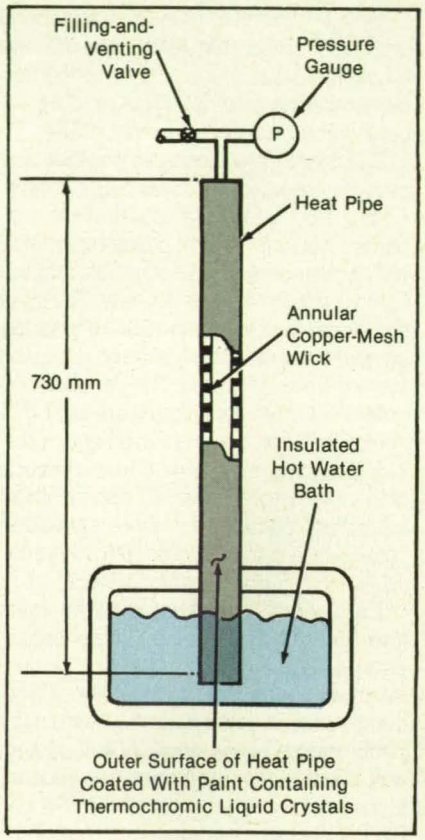

Figure 1. This **Heat Pipe** is coated with thermochromic liquid crystals to make the distribution of temperature visible.

After several minutes of steady-state operation, the rainbow-colored region had progressed about 12 cm up the solid rod and had spread over a several-centimeter region; this is characteristic of mild thermal gradients. However, the entire heat pipe continued to be iridescent, with the selective reflection of bright colors. When noncondensible gas (air) was within the heat pipe, a distinct cold region was noticeable above the condenser region. Also noticeable was the compression of the air-filled region during initial heating. When the vent valve on the top of the heat pipe was briefly opened, the air escaped, and the distinct rainbow boundary of the region of noncondensible gas rapidly progressed to the end of the heat pipe.

This work was done by Fred S. Gunnerson and Glen E. Thorncroft of the University of Central Florida for **Kennedy Space Center**. *For further information, Circle 97 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 20]. Refer to KSC-11577.

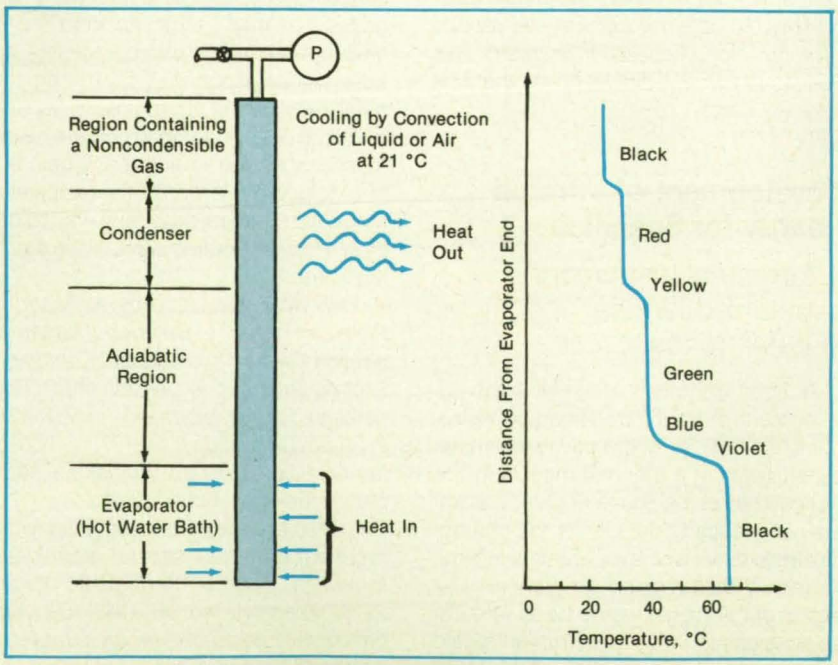

Figure 2. The **Distribution of Temperature** along a heat pipe that contains noncondensible gas is revealed by the colors of the TLC paint on its outer surface.

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Books and Reports

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Degree of Development of Waves and Bias in Radar Altimetry

An empirical correction for the sea-state bias is developed.

A report discusses the relationship between the degree of development of waves and the sea-state bias (which is defined below) in radar altimetry. The purpose of this and related studies is to increase the accuracy of estimates of sea-state bias and thereby increase the accuracy of estimates of the sea level that would be obtained if the waves at the measurement spot were suppressed. In this study, it is shown that the sea-state bias is related to a parameter called the "pseudo wave age."

The round-trip time of the altimetric radar pulses is directly related to the mean height of the specular facets of the sea surface at the measurement spot, and therefore yields an estimate of the mean height of the surface of that spot. The design of a typical radar altimeter incorporates the assumption that the statistical distribution of surface elevations in wind-generated waves is Gaussian. In practice, the distribution deviates from Gaussian, and this deviation gives rise to electromagnetic and statistical effects that alter the estimate, by the radar altimeter, of the mean surface height. The sea-state bias (SSB) is the amount of this alteration.

The point of departure of this study is the recognition that the altimetric SSB depends on both the heights and the histories of waves: Newly generated waves are more skewed than older waves are, and consequently, the probability density function of their surface heights is less Gaussian. This concept leads to the notion that the SSB should be a function of some measure of the ages and heights of waves.

The chosen measure of height is the significant wave height ($H_{1/3}$), which is one of the outputs of the radar altimeter. The pseudo wave age mentioned earlier is the chosen measure of age, and it is an extension of the similarly named wave age, which is defined as C/U, where C is the phase speed of the dominant wave and U is the windspeed when the sea is in equilibrium with the wind. (Note that the wave age is not an age, but a dimensionless number that is plausibly related to age.) The pseudo wave age can be expressed in terms of $H_{1/3}$ and U. Under more-general conditions when the sea is not in equilibrium with the wind, the pseudo wave age does not equal the wave age. Nevertheless, it serves as a rough indicator of the degree of development of waves.

In this study, the general trend in the dependence of the SSB on pseudo wave age was found by analysis of 2.7 years' worth of Geosat data. The analysis confirms the theoretical prediction that for a given $H_{1/3}$, the SSB decreases as the degree of development (as quantified by the pseudo wave age) increases. This empirical trend is modeled as

$$\mathrm{SSB} = A\left(\frac{\xi}{\xi_m}\right)^M H_{1/3}$$

where ξ and ξ_m are the pseudo wave age and its average value, respectively; $A = 0.013 \pm 0.005$; and $M = -0.88 \pm 0.37$. Statistically, this model performs slightly better than does a standard model (SSB = $\beta H_{1/3}$ where β is a constant). This model reduces the global root-mean-square error of the estimate of SSB by 1.6 cm. However, the main advantage of the model is that it reduces false geographic and seasonal trends in the mean sea level, the trends associated with geographic and seasonal variability of the wave age.

This work was done by Lee-Lueng Fu and Roman Glazman of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "The Effect of the Degree of Wave Development on the Sea-State Bias in Radar Altimetry Measurement," Circle 34 on the TSP Request Card.*

NPO-18392

Calorimetric Vacuum Emissometry at 773 to 923 K

CVE measurements take more time but are more accurate than are those of other techniques.

A report describes the design, construction, and tests of a calorimetric vacuum emissometer (CVE) intended to measure the total hemispherical emittances of materials in a vacuum at temperatures from 773 to 923 K. Results of measurements by the CVE are compared with those of a hohlraum (blackbody) reflectometer and an open-air elevated-temperature emissometer.

The hohlraum reflectometer measures a hemispherical spectral reflectance of a specimen at room temperature, and the open-air emissometer measures the spectral emittance perpendicular to the surface of a specimen at the desired elevated tem-

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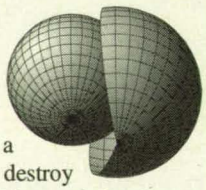

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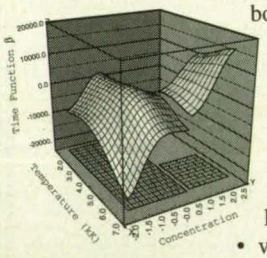

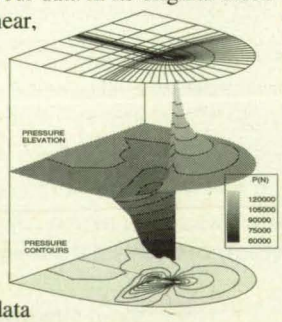

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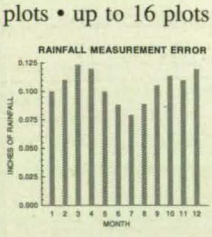

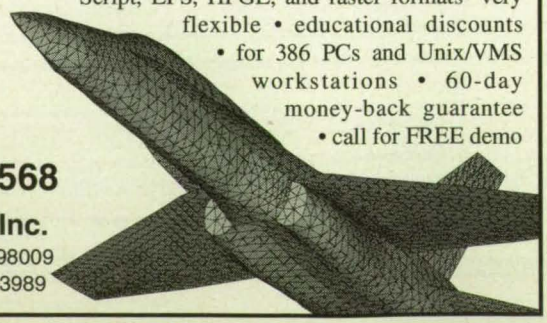

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perature. The total hemispherical high-temperature emittance can be deduced from such measurements, but the deductions are based on mathematical models that involve assumed angular dependences and the assumed constancies of emissivities and reflectivities under changes of temperature.

In contrast, CVE measurements do not depend on mathematical models and are nearly immune from the foregoing complications. The specimen is heated in a vacuum to the desired temperature at which emittance is to be determined, and the walls of the calorimetric cavity collect nearly all the thermal radiation emitted at all angles by the surface of the specimen.

The CVE used in this study was originally designed for use at 323 to 423 K. This instrument was left mostly unchanged, except that its specimen holder and heater were redesigned to enable operation at 773 to 923 K. The modified CVE was used to measure the emittances of plasma-sprayed alumina, carbon paint on stainless steel, arc-textured titanium, sandblasted niobium/zirconium alloy, high-temperature black paint, sanded stainless steel, polished copper, and polished stainless steel. The results of these measurements were compared with those of a hohlraum reflectometer and an open-air emissometer. Differences were attributed to temperature, atmospheric, and directional effects and to errors in the hohlraum and emissometer measurements (±5 percent). The probable error of the CVE measurements was found to be typically less than 1 percent.

The principal advantage of a hohlraum-reflectometer measurement is that it requires less than an hour, while a CVE measurement takes much longer because of the time required to attach the thermocouple to the specimen, pump down the system, and bring the specimen to thermal equilibrium. Thus, the hohlraum reflectometer is useful for screening or preliminary measurements of, say, candidate thermal-radiator materials. Materials that survive the screening could then be placed in the CVE to obtain more reliable measurements.

This work was done by Michael J. Mirtich and Bruce A. Banks of **Lewis Research Center**, *Curtis Stidham and Michael Kussmaul of Cleveland State University, and Frank DiFlippo of Case Western Reserve University. Further information may be found in NASA TM-102322 [N90-10309], "Total Hemispherical Emittance Measured at High Temperatures by the Calorimetric Method."*

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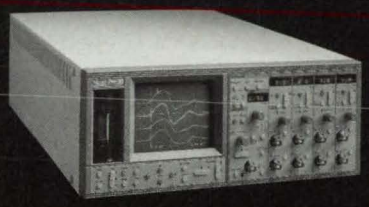

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Improved Composite Flexible Blanket Insulation

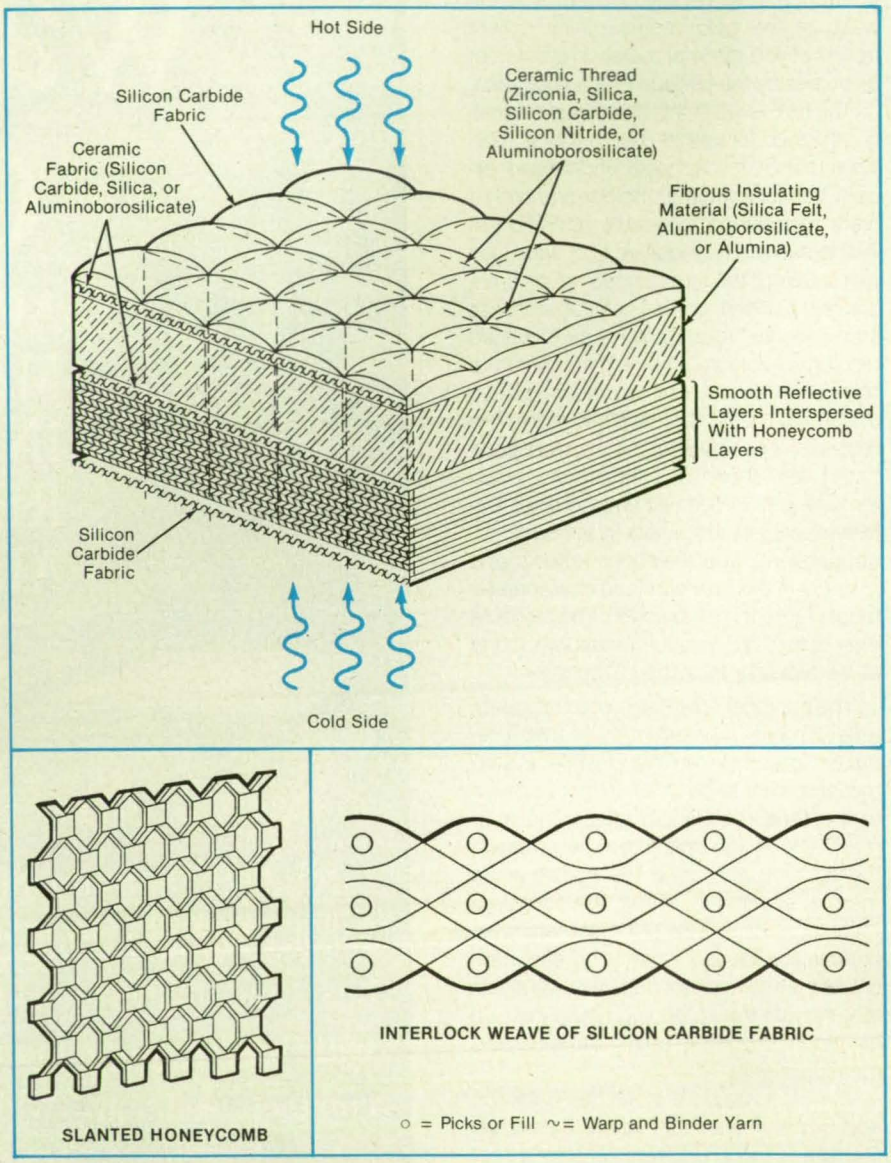
Lightweight blankets have low effective thermal conductivities.

Ames Research Center, Moffett Field, California

An improved class of composite flexible blanket insulation has been developed by taking advantange of advanced lightweight materials. The insulating blankets were intended originally to protect spacecraft against heating during reentry into the atmosphere but could also be used on Earth where there are requirements for lightweight, flexible, highly efficient insulating materials that can protect people and equipment against temperatures up to about 1,650 °C. They could be used, for example, as furnace curtains and as insulating layers on firefighting equipment and protective clothing.

The figure shows the structure of a typical improved composite flexible insulating blanket. The blanket is stitched together in a quilted pattern with a ceramic thread. The top side is the one that is exposed to the high temperature. The top and bottom layers are made of silicon carbide fabric, preferably with a three-ply interlock weave as shown in the detail at the bottom of the figure. The interlock weave provides a surface density and, therefore, a thermal emittance greater than those of other weaves commonly used in silicon carbide fabrics. This is an advantage in aeroconvective-heating environments like those of the original spacecraft application, in which one relies on outward reradiation of heat from the top surface to reduce the temperature of the top surface and thereby provide part of the thermal protection.

A layer of fibrous ceramic insulating material is sandwiched between the top fabric layer and an intermediate fabric layer. Below the intermediate fabric layers are multiple (typically 10) smooth reflecting layers of Kapton (or equivalent) polyimide film aluminized on one surface. These smooth reflective layers are interspersed with layers of slanted honeycomb also made of plastic film, metal foil, or a combination film like the aluminized polyimide of the reflecting layers. Together, the interspersed layers retard the radiative transfer of heat, and the walls of the honeycomb further retard the convective transfer of heat. Experiments have shown that the singly aluminized smooth reflecting layers insulate more effectively at high temperatures than do the doubly aluminized reflecting layers used in some prior multilayer insulating materials. The thermal diffusivity, thermal conductivity, and weight of the honeycomb layers are less than those of prior insulating materials used in the same temperature range.



Improved Composite Flexible Blanket Insulation is a quilt of layers of advanced lightweight insulating materials. Each layer is designed to optimize its contribution to the inhibition of the radiative, conductive, and/or convective transfer of heat from the hot side to the cold side.

This work was done by D. A. Kourtides and D. M. Lowe of **Ames Research Center**. *For further information, Circle 37 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center [see page 20]. Refer to ARC-11955.

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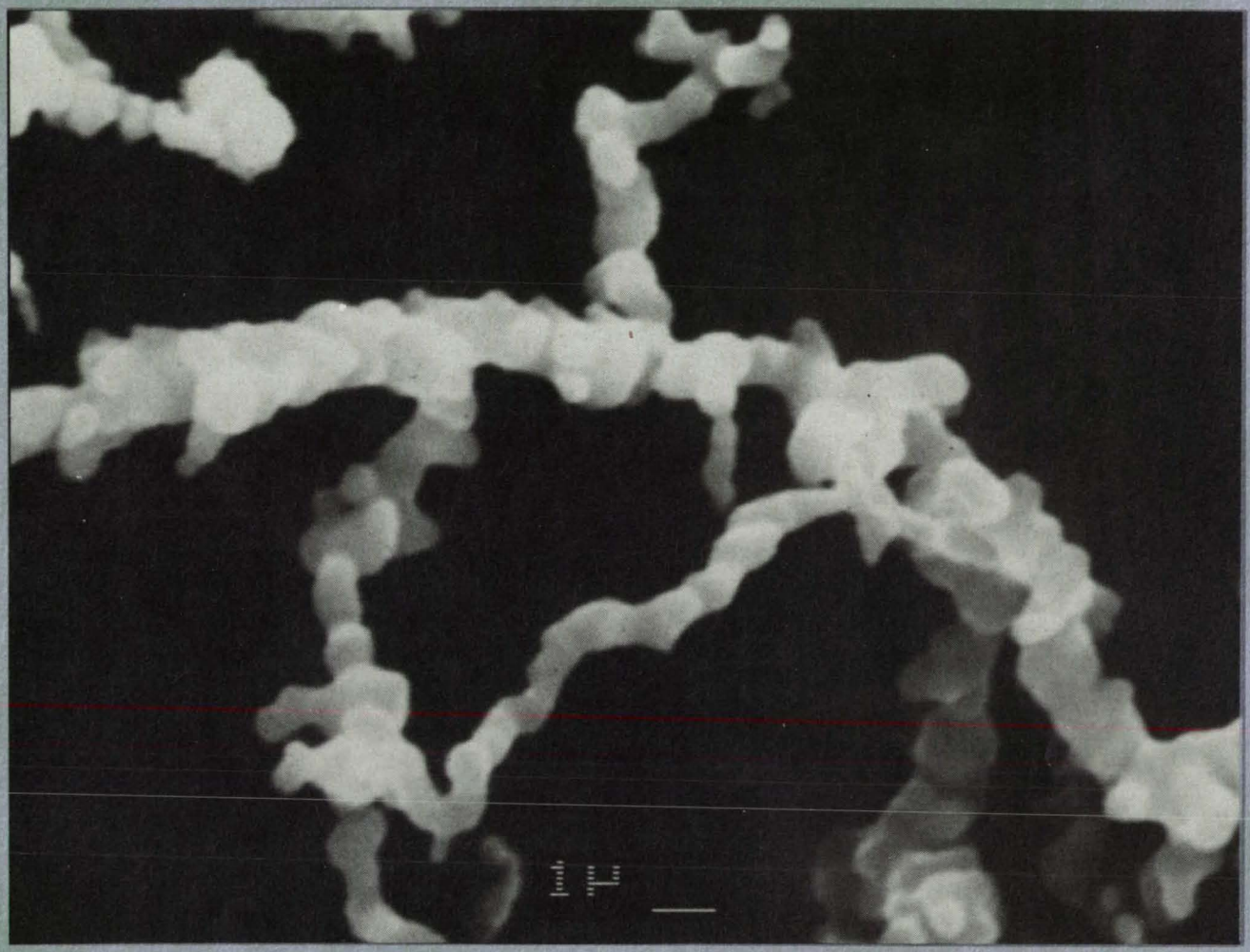

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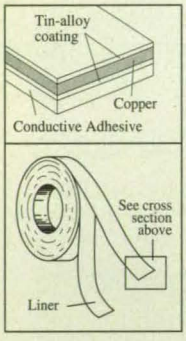
3M Reveals New Long Term EMI/RFI Shielding Tape

Tin-alloy coating on both sides of copper foil offers superior solderability, environmental stability.

AUSTIN, Tex. — This new UL Recognized Scotch™ Foil Shielding Tape 1183 employs a tin-alloy coating on smooth copper foil to produce a durable and effective electromagnetic shield.



The tin-alloy coating is on both sides of the copper for thorough protection.

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Poly(1,2,4-Triazoles) Via Aromatic Nucleophilic Displacement

Synthesis involves nucleophilic displacement of monomers with activated aromatic dihalides.

Langley Research Center, Hampton, Virginia

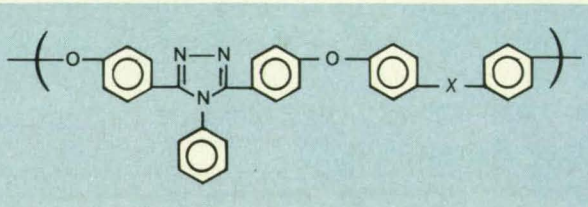
Novel poly(1,2,4-triazoles) (PT) have been prepared by the aromatic nucleophilic displacement of di(hydroxyphenyl)-1,2,4-triazole monomers with activated aromatic dihalides. The reactions were carried out in polar aprotic solvents such as sulfolane and diphenylsulfone, using alkali metal bases such as potassium carbonate at elevated temperatures under nitrogen. The di(hydroxyphenyl)-1,2,4-triazole monomers were synthesized by reacting bis(4-hydroxyphenyl)hydrazide with aniline hydrochloride at 250 °C in the melt and by reacting 1,3- or 1,4-bis(4-hydroxyphenyl)phenylenedihydrazide with aniline hydrochloride in the melt. Purification of the di(hydroxyphenyl)-1,2,4-triazole monomers was accomplished by recrystallization.

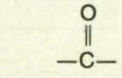
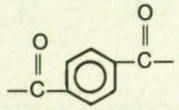
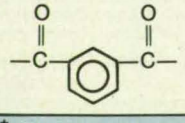
The polymers exhibited desirable physical and thermal properties. Selected characteristics of three polymers are presented in the table in the figure. The inherent viscosities (η_{inh}) of the PT ranged from 1.37 to 3.4 dL/g, and the glass-transition temperatures (T_g) ranged from 192 to 216 °C. One polymer exhibited a crystalline melting temperature (T_m) of 377 °C. Thermogravimetric analysis showed no loss of weight below 300 °C, and a 5-percent loss of weight at approximately 500 °C, in both air and nitrogen.

This route for the synthesis of polymers provides high-molecular-weight PT of new chemical structures, is potentially more economically favorable than other routes, and, because of the availability of a large variety of activated aromatic dihalides, provides for facile variation of chemical structure. These polymers should be useful for producing films, moldings, adhesives, and composites.

This work was done by John W. Connell and Paul M. Hergenrother of **Langley Research Center** *and Peter Wolf of BASF Corp. For further information, Circle 38 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14440.



X	η_{inh}, dL/g	T_g, °C	T_m, °C
	2.94	207	ND*
	3.40	216	377
	1.37	192	ND*

*ND = Not Detected by DSC.

Selected Characteristics of Three Poly(1,2,4-Triazoles) are listed.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Research on Bi-Based High-Temperature Superconductors

The bismuth-based high-temperature superconductor system was investigated.

A brief report describes the effects of melt sintering on a Bi-based high-temperature superconductor system, as well as the use of a vibrating-sample magnetometer to determine hysteresis curves at 77 K for partially melt-sintered samples. Also briefly discussed is the production of high-temperature superconducting thin films by laser ablation: such films are potentially very useful in the detection of signals of very low power.

The Bi-based superconductor system studied was $Bi_2Sr_2Ca_{n-1}Cu_nO_{4+2n}$, where $n = 1, 2,$ or 3. The values of n correspond to phases that have critical temperatures (T_c's) of 22 K, 85 K, and 110 K, respectively. Experiments were performed in the hope of enhancing the superconducting properties of the 2223 ($n = 3$, $T_c = 110$ K) phase by the substitution of Pb and Sb for Bi. New steps were taken in the preparation to increase homogeneity of Pb and Sb-substituted specimens and to decrease the sizes of particles of powders used to make them: After the initial powders were weighed, mixed, and coarsely ground, they were deposited into a ball mill with ethyl alcohol and ground for several hours. The alcohol was then evaporated from the powder mixture by placing the mixture in a furnace set at a temperature of 200 °C. The remaining sediment was heated in powder form to 810 °C for 20 h, reground, and pressed into pellets under a pressure of 6,000 psi (41 MPa). X-ray diffraction scans demonstrated these preheated powders to be a mixture of 2201 ($n = 1$, $T_c = 22$ K), 2212 ($n = 2$, $T_c = 85$ K), and Pb/Sb-dominated phases.

The attempt to substitute Sb into the 2223 phase proved successful, as determined to the limits of x-ray diffraction measurements. Transport measurements revealed no significant enhancement of the superconducting properties, as previously reported for nominal compositions of this phase.

A surprising melt-sintering effect was discovered in nominally substituted Sb/Bi/Pb compounds. Although specimens of these compounds were initially multiphased, melt-sintering conditions gave rise to film-like regions on the surfaces of the specimens. These layers were c-axis oriented and consisted of the 2201, 2212, and 2223 phases. The amount of each phase could be controlled by control of the conditions of preparation.

A vibrating-sample magnetometer system was constructed and tuned. This system is capable of magnetic characterization of superconductors and will be used to investigate both specimens prepared in this study and specimens from previous work. This apparatus was used to take hysteresis curves of partially melt-sintered specimens of YBa_2/Cu_3O_7 at a temperature of 77 K. The areas enclosed by the curves were found to become larger as specimens that were increasingly melt-sintered were tested. This is a result of more flux trapping in the melt-sintered specimens than in the sintered specimens.

Finally, preliminary steps were taken to set up an apparatus for the production of high-temperature-superconducting thin films by laser ablation. In the laser-ablation process, a high-energy pulse of ultraviolet light (1 to 2 J/cm^2, 12 ns) vaporizes the surface of a target made of the desired material; a perpendicularly emitted plume

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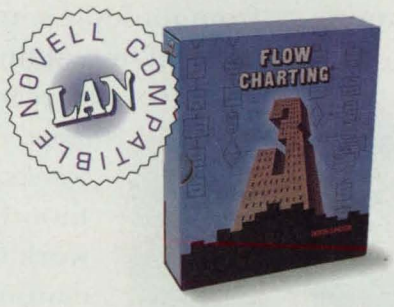

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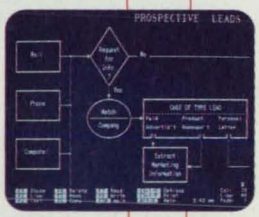

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of gaseous material then coats a heated substrate.

This work was done by Curtis Banks, George B. Doane III, and John Golben of the University of Alabama in Huntsville for **Marshall Space Flight Center**. *To obtain a copy of the report, "High Temperature Superconductor Materials and Applications," Circle 65 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-27264.

Electrochemical Impedance Spectroscopy of Metal Alloys

The polarization resistances of 19 alloys in chloride solutions were measured.

A report describes the use of electrochemical impedance spectroscopy (EIS) to investigate the resistances of 19 alloys to corrosion under conditions similar to those of the corrosive, chloride-laden seaside environment of the Space Transportation System launch site. The alloys investigated were Hastelloy C-4, C-22, C-276, and B-2; Inconel* 600, 625, and 825; Inco* G-3; Monel 400; Zirconium 702; Stainless Steel 304L, 304LN, 316L, 317L, and 904L; 20Cb-3; 7Mo+N; ES 2205; and Ferralium 255. Electrochemical ac impedance measurements were performed on specimens immersed for 1 hour or longer in each of the following three electrolyte solutions: 3.55 percent aqueous NaCl, 3.55 percent NaCl in 0.1N HCl, and 3.55 percent NaCl in 1.0N HCl. The data were analyzed qualitatively by use of Nyquist plots and quantitatively by use of Bode plots. Values of polarization resistance, R_p, were obtained from the Bode plots. (R_p is considered to be a measure of resistance to corrosion. The rate of corrosion under the given conditions is approximately proportional to $1/R_p$.)

Of the alloys tested, Zirconium 702 was the most resistant to corrosion in the three electrolytes. The orders of the other alloys according to their resistances to corrosion differed at the different concentrations of hydrochloric acid in the electrolyte. The corrosion resistances of Zirconium 702 and Ferralium 255 increased with the concentration of hydrochloric acid; the corrosion resistances of the other 17 alloys decreased with the concentration of hydrochloric acid.

Alternating-current impedance data on all of the alloys except Stainless Steel 304LN, were gathered at various immersion times in the solution that consisted of 3.55 percent NaCl in 0.1N HCl. R_p was obtained from the Nyquist plot at each immersion time by processing the measurement data via the EQUIVALENT CIRCUIT software available with the impedance-measuring equipment. The R_p of Hastelloy C-22 showed the highest overall values of R_p, while Monel 400 and Inconel 600 exhibited the lowest overall values.

The corrosion performances of specimens exposed outdoors at a beach corrosion-testing site were found to be well correlated with rates of corrosion predicted on the basis of R_p values obtained from the laboratory impedance measurements. These results suggest that electrochemical impedance spectroscopy can be used to predict the corrosion performances of metal alloys.

*"Inco" and "Inconel" are registered trademarks of the Inco family of companies.

This work was done by L. G. MacDowell and L. M. Calle of **Kennedy Space Center**. *To obtain a copy of the report, "Evaluation of High Performance Metal Alloys in the STS Launch Environment Using Electrochemical Impedance Spectroscopy," Circle 29 on the TSP Request Card.*
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Electronic Systems

Simulating the SSF Information System

FROST provides statistics on the generation, communication, and processing of data.

The information system of the Space Station *Freedom* (SSF) is intended to process and transmit data between the space station and the station controllers and payload operators on the ground. Components of the system would include flight hardware, communications satellites, software, and ground facilities. The Freedom Operations Simulation Test (FROST) computer program simulates the operation of the SSF information system, tracking every packet of data from generation to destination, for both uplinks and downlinks. This program collects various statistics concerning the operation of the system and provides reports of these statistics at intervals specified by the user. In addition, FROST incorporates graphical-display capability to enhance interpretation of these statistics.

FROST mathematically models each of the components of the SSF information system as an object, in which packets of data are generated, received, processed, transmitted, and/or dumped. The user must provide the design of the information system, including specified parameters and interconnections among objects. To aid this process, FROST supplies an example SSF information system for simulation, but this example must be copied before it is changed and used for further simulation.

Once specified, architecture and parameters of the system are put into the input file, named the Test Configuration Definition (TCD) file. Alternative designs of the system can then be simulated simply by editing the TCD file. Within this file, the user can define new objects, alter the parameters of objects, redefine paths, redefine generation rates and windows, and redefine interconnections among objects. At present, FROST does not model every feature of the SSF information system, but it is capable of simulating many of the important functions of the system.

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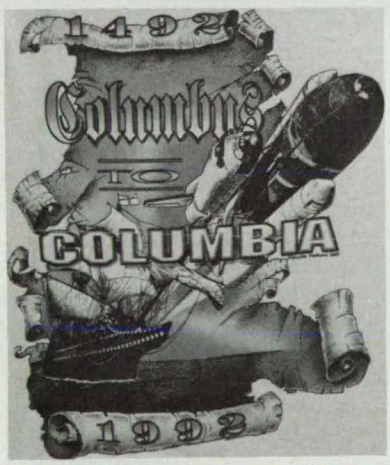

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come from any object, FROST defines "windows" to specify when, what kind, and how much information is generated. All messages are classified by priority as either (1) emergency, (2) quick-look, (3) telemetry, or (4) payload data. These messages are processed by all objects according to priority. That is, all priority 1 (emergency) messages are processed and transmitted before priority 2 messages are processed, and so forth. FROST also allows for specification of "pipeline" or "direct" links. Pipeline links are used to broadcast at constant intervals, while direct links transmit messages only when packets are ready for transmission.

FROST allows the user substantial flexibility to customize output for a simulation. Output consists of tables and graphs, as specified in the TCD file, to be generated at the specified intervals. These tables can be generated at short intervals during the run to produce snapshots as simulation proceeds, or generated after the run to give a summary of the entire run.

FROST is written in SIMSCRIPT II.5 (developed by CACI) for DEC VAX-series computers running VMS. FROST was developed on a VAX 8700 computer and is intended to be run on large VAX computers with at least 32 Mb of memory. The main-memory requirement for FROST depends on the number of processors used in the simulation and the event time. The standard distribution medium for this package is a 9-track, 1,600-bit/in. (630-bit/cm) DEC VAX BACKUP format magnetic tape. An executable code is included on the tape in addition to the source code. FROST was developed in 1990.

DEC, VAX, and VMS are registered trademarks of Digital Equipment Corp. IBM PC is a trademark of International Business Machines Corp. SIMSCRIPT II.5 is a trademark of CACI.

This program was written by Govind K. Deshpande, Henry Kleine, Joseph C. Younger, Felicia A. Sanders, Jeffrey L. Smith, Robert W. Aster, Jerry M. Olivieri, and Lori L. Paul of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 36 on the TSP Request Card.*
NPO-18484

Mechanics

Analyzing Stresses in Orthotropic Materials

BOFFO implements the boundary-force method.

In fracture mechanics, stress-intensity factors are important parameters that are used in predicting fracture strengths and fatigue lives. The Boundary Force Method for Orthotropic Materials (BOFFO) computer program performs stress analyses of two-dimensional, linearly elastic, orthotropic or composite bodies with or without cracks, by use of the boundary-force method. The boundary-force method is versatile in that it makes it possible to analyze complicated geometries, crack configurations, and load distributions with ease. The BOFFO program is easy to use because in BOFFO, only the boundaries of the region of interest are modeled mathematically by use of a built-in mesh generator. Stresses can be computed at any specified point in the body. Solutions that involve stress-intensity factors and strain-energy-release rates are computed for both mode-I and mixed-mode fracture problems.

The boundary-force method is a numerical technique in which one uses the fundamental solutions for concentrated forces and moments in an infinite sheet to obtain the solution to the boundary-value problem of interest. These fundamental solutions are used in the BOFFO program to satisfy the stress-free conditions exactly on the faces of cracks. The other boundary conditions are satisfied approximately by applying the appropriate sets of concentrated horizontal and vertical forces and moments along the boundaries.

The configuration appropriate to a given problem is defined with the help of two sets of axes. The global *X* and *Y* axes are used to define the boundaries of, loads upon, and properties of materials in, the specimen. The local axes define the length and orientation of the crack. The user can specify four types of symmetry conditions: symmetry about the *X* axis, symmetry about the *Y* axis, symmetry about the *X* and *Y* axes, or no symmetry. The lines of symmetry are not modeled as boundaries. The accuracy of the solution depends on how well the boundary conditions are approximated; this, in turn, depends on the refinement of the boundary mesh. BOFFO uses the radial-line method to generate the mesh.

BOFFO is written in FORTRAN V for execution on CDC CYBER 170-series computers running NOS. The execution time and memory required depend on the number of boundary elements in the mesh. With 12 elements, the required main memory is 26K CYBER words. Input and output are tabular. BOFFO is available on a 9-track, 1,600-bit/in. (630-bit/cm) ASCII Card Image format magnetic tape. This program was developed in 1990.

CDC CYBER and NOS are trademarks of Control Data Corp.

This program was written by Catherine A. Bigelow of **Langley Research Center** *and Paul W. Tan of Analytical Services & Materials, Inc. For further information, Circle 59 on the TSP Request Card.*
LAR-14650

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NASA Software Update

Each month *NASA Tech Briefs* features new computer programs available through COSMIC, NASA's Computer Software Technology Transfer Center in Athens, Georgia. In addition to creating new programs, NASA continually updates and enhances existing software. Programs updated in the past year include:

Systems Improved Numerical Differencing Analyzer and Fluid Integrator (SINDA '85/FLUINT) This comprehensive thermal analysis system handles complex models such as evaporators and permits the interaction of thermal and fluid problems. Design flexibility is provided by 20,000 nodes, 100,000 conductors, 100 thermal submodels, and 10 fluid submodels. SINDA '85/FLUINT is available for DEC VAX, DEC RISC, Sun, Cray, and Convex computers. *Circle 98 on the TSP Request Card. MSC-21528.*

Thermal Radiation Analyzer System (TRASYS) Working alone or with SINDA '85/FLUINT, TRASYS solves the radiation components of thermal analysis problems. A TRASYS model calculates both the internode radiation exchange and the incident and absorbed heat rate due to sunlight. Used in satellite design, the program can handle situations where one surface wholly or partially shades another from direct sunlight. It is available for DEC VAX and Cray computers. *Circle 99 on the TSP Request Card. MSC-21030.*

Science & Technology Laboratory Applications Software (ELAS) This digital image analysis system processes Landsat multispectral data, aircraft-acquired scanner data, digitized topographic data, and such ancillary data as soil types and rainfall information. Over 230 modules aid the user in performing a wide range of land cover analyses and manipulations. ELAS runs on Concurrent, DEC VAX, Sun, Masscomp, and Silicon Graphics computers. *Circle 101 on the TSP Request Card. ERL-10017.*

Structural Analysis of General Shells (STAGS) models complex thin shell structures including separate shell branches or segments connected along their boundaries. Options include static stress and vibration, transient, and bifurcation buckling analysis. Also useful for submarine design, STAGS is available for DEC VAX, DEC RISC, Cray, Convex, Sun, Silicon Graphics, IBM RS/6000, HP9000, and Stardent Titan systems. *Circle 102 on the TSP Request Card. HQN-10967.*

NETS The NETS development tool provides an environment for simulation and development of neural networks—computer programs that "learn" from experience. Written in ANSI standard C, the program allows the user to generate C code for implementation of a neural network. NETS can run on a Macintosh computer or as a machine-independent program. *Circle 103 on the TSP Request Card. MSC-21588.*

Programs to Optimize Simulated Trajectories (POST\6DPOST) Designed for optimizing simulated trajectories, POST is a point mass, three degrees-of-freedom program while the extended 6DPOST permits rigid-body six degrees-of-freedom models. The package runs on Sun and Silicon Graphics computers and handles sophisticated problems such as ascent, orbital maneuvers, and reentry. *Circle 104 on the TSP Request Card. LAR-13938.*

Global Reference Atmosphere Model (GRAM) This 4D model provides atmospheric parameter values either automatically at positions along a linear path or along any set of connected positions specified by the user. Based on actual data, GRAM provides thermal wind shear for the monthly mean winds, the percent deviation from the standard atmosphere, the mean vertical wind, and the perturbation data for each position. *Circle 105 on the TSP Request Card. MFS-28397.*

PC-SEAPAK is an interactive satellite data analysis software package developed for oceanographic research. The PC program is used to process data from the Nimbus-7 Coastal Zone Color Scanner and the NOAA Advanced Very-High-Resolution Radiometer. *Circle 106 on the TSP Request Card. GSC-13320.*

Time Warp Operating System (TWOS) Designed to support parallel discrete-event simulation, TWOS is a complete implementation of the Time Warp mechanism—a distributed protocol for virtual time synchronization based on process rollback and message annihilation. The program runs on Sun computers and the BBN Butterfly GP-1000. *Circle 107 on the TSP Request Card. NPO-18692.*

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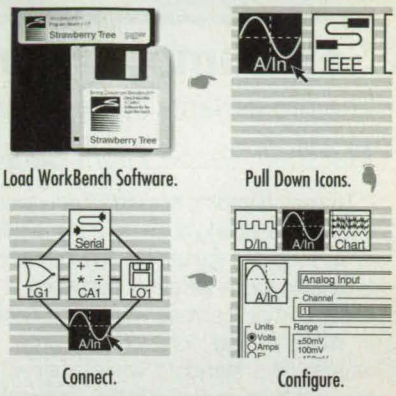

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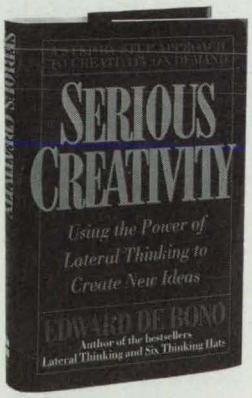

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Self-Damping Sprung Wheel

The rim deflects in the vicinity of the contact with the ground or floor.

Marshall Space Flight Center, Alabama

The self-damping sprung wheel provides a shock-absorbing suspension for a wheelchair, reducing the user's discomfort when traversing rough terrain or obstacles. A pair of self-damping sprung wheels are installed in place of the conventional large rear wheels of a standard wheelchair, which the user then operates in the conventional manner.

Other types of shock-absorbing suspensions are not suitable for wheelchairs. For example, when a rigid wheel on a spring suspension encounters an obstacle, the entire wheel is pushed upward, and the top of the wheel can make contact with the user's arm. In addition, the handwheel portion vibrates along with the rest of the wheel; this makes it difficult for the user to grasp and apply force to the handwheel. In contrast, the self-damping sprung wheel does not rise and fall in its entirety; the only part that deflects is a portion of the rim in the vicinity of the contact with the floor, ground, and/or obstacle.

The wheel includes a central hub that turns on conventional bearings, with radial spokes extending from the hub to a flexible rim (see Figure 1). The handwheel is attached to the spokes near their outer ends. A slot in the outer end of each spoke accommodates the radial sliding of a cylindrical knob attached to a rim connector tang. In the normal undeflected condition, the rim spring-loads every cylindrical knob radially outward against a cover plate, which retains the knob in the slot. When a portion of the rim is deflected radially inward by contact with an obstacle, the knob(s) in the affected spoke(s) slide radially inward along the slot(s).

As shown in Figure 2, the rim includes thin inner and outer hoops of molded reinforced plastic, plus an elastomeric intermediate hoop bonded to the inner and outer hoops. Tire-retaining tabs are attached to the outer hoop, and a standard airless polyurethane-foam wheelchair tire is mounted on the tabs. Where part of the tire and rim are deflected inward, the outer hoop is loaded in compression, the inner hoop is loaded in tension, and the elastomeric intermediate hoop is loaded in shear. The shear deformation of the elastomer absorbs the energy stored in the bending of the rim, thereby providing damping.

An alternative version of the wheel could be designed for a bicycle. The tire-retaining tabs and wheelchair tire would be replaced by a continuous-strip retainer and pneumatic tire, the handwheel and its mounting fixtures would be deleted, the stiffness of the rim would be changed to accommodate greater speeds, and the hub would be modified to accommodate bicycle-style bearings and fork mounting.

This work was done by Bruce Weddendorf of **Marshall Space Flight Center**. *For further information, Circle 27 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-28632.

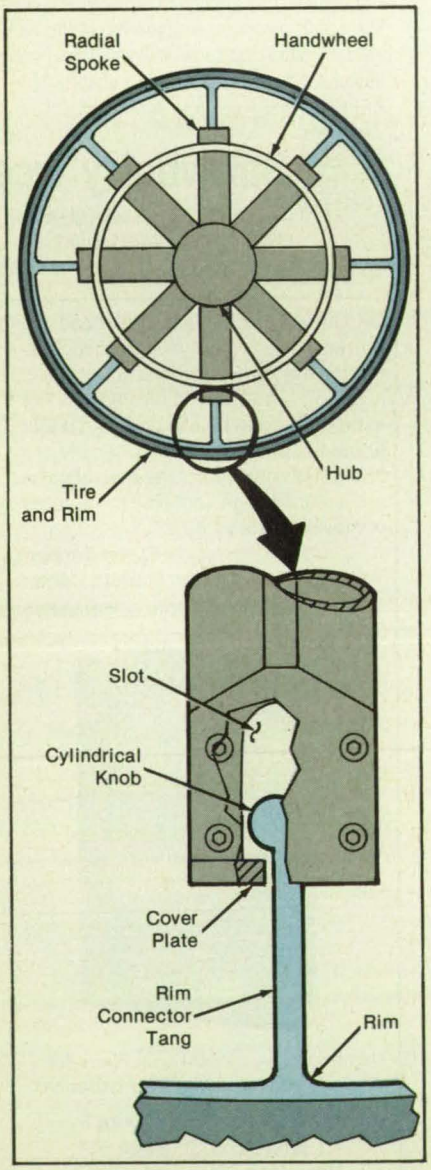


Figure 1. The **Knob Slides In the Slot** to accommodate deflection of the rim.

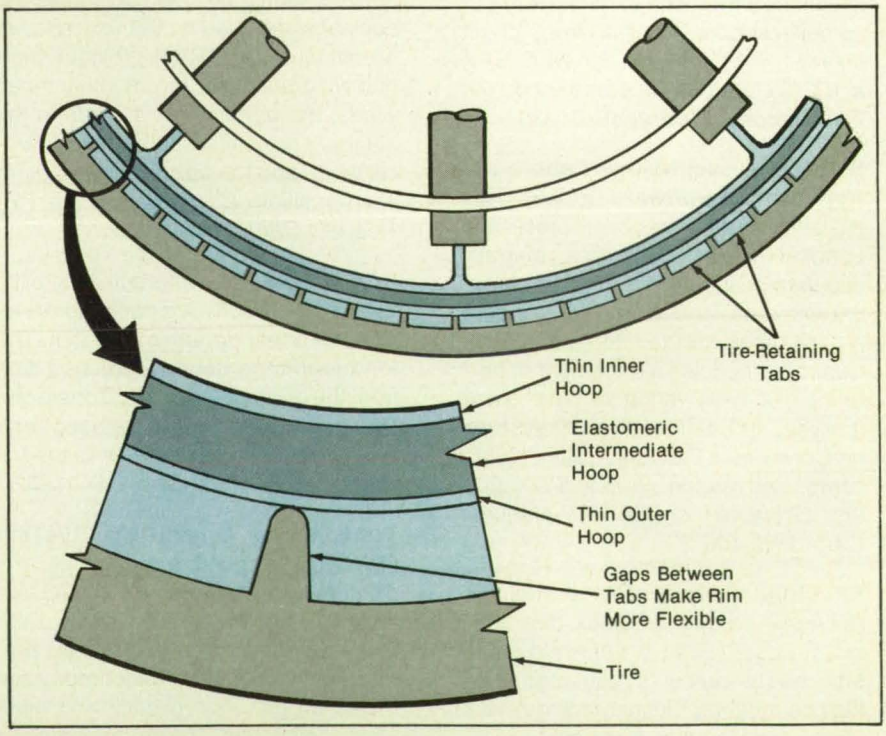


Figure 2. The **Rim Includes Inner and Outer Hoops** that bend when an obstacle is encountered. The shear deformation of the elastomeric hoop between them absorbs energy. Thus, the three hoops act together as a damping spring.

Viscous/Inviscid Interaction on an Oscillating Airfoil

A computational procedure simulates complicated flow phenomena.

Ames Research Center, Moffett Field, California

A viscous/inviscid-interaction procedure has been developed for computation of the two-dimensional flow of air about an airfoil, the angle of attack of which oscillates at high amplitude (see figure). The purpose of this and similar procedures is to study the flow effects in dynamic stall, which is the unsteady condition that occurs on such airfoils as the blades of helicopter rotors, windmills, and turbomachinery cascades when the angle of attack of the airfoil dynamically exceeds the angle at which the airfoil would stall in steady flow.

As is common in computations of unsteady flows of viscous fluids, in this procedure the bulk of the flow is treated as inviscid, while the effects of viscosity are treated only on the surface of the airfoil and in the boundary layer. The inviscid part of the flow is simulated via a time-marching, unsteady-subsonic-flow panel method that incorporates appropriate distributions of unsteady surface and wake singularities.

The principal novel feature of this procedure is its provision for coupling between the panel method and a finite-difference code that calculates the unsteady laminar/turbulent boundary-layer flows about oscillating airfoils. The boundary-layer code is based on an inverse boundary-layer formulation that is an extension, to the unsteady case, of a method developed previously for steady flows and that is based on a Hilbert-integral formulation. Here, the Hilbert-integral concept is used in regions of strong viscous interaction, with several successive sweeps through the boundary layer per time step. A few global iterations in combination with the inviscid method are necessary to get a final converged solution for a complete cycle of oscillation. For turbulent flows, a two-region algebraic eddy viscosity is used on a quasi-steady basis. The location of the transition from laminar to turbulent flow is prescribed in space and time.

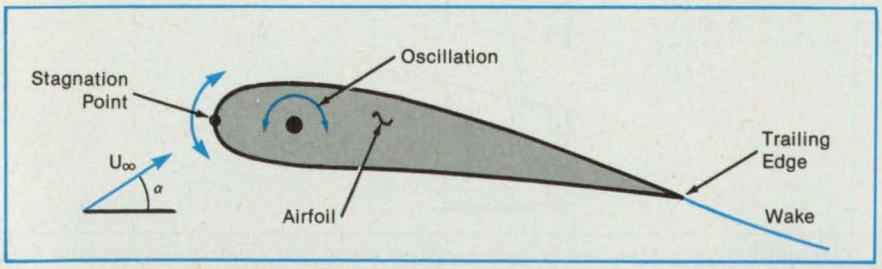
The problem of the motion of the region of integration because of movement of the front stagnation point is solved by a new transformation that involves a time-variable boundary-layer grid. The effect of wake circulation is taken fully into account in the inviscid part of the problem via the unsteady Kutta condition. The displacement effect of the wake, however, is simply accounted for by an algebraic equation that represents a distribution of sinks with exponential decay along the centerline of the wake.

The procedure has been applied to a number of cases of dynamic airfoil motion involving angles of incidence up to 18°, various reduced frequencies (including the quasi-steady case), various Reynolds numbers, and various airfoil sections. The comparisons with experimental data show reasonably good agreement, even for the coefficients of unsteady drag.

Based on research using this method, several areas have been identified that require further investigation. The subsonic (incompressible) treatment reaches its limits in high-incidence cases because of the development of supersonic regions and shock waves in the leading-edge area of the airfoil. The algebraic representation of the displacement effect of the wake is only approximate. The unsteady movement of transition has been rigidly and, therefore, unrealistically attached to the increment of the stagnation point. The quasi-steady application of the two-region algebraic eddy viscosity is also only approximate. These shortcomings may be overcome in the future by further development of the coupling scheme.

This work was done by L. W. Carr of **Ames Research Center**, *W. Geissler of DFVLR Institute of Aeroelasticity, and T. Cebecci of California State University. For further information, Circle 96 on the TSP Request Card.*

ARC-12472



The **Flow About an Oscillating Airfoil** is simulated by a computational procedure based on the concept of interacting viscous and inviscid flows.

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Lightweight Right-Angle Valve for Cryogenics

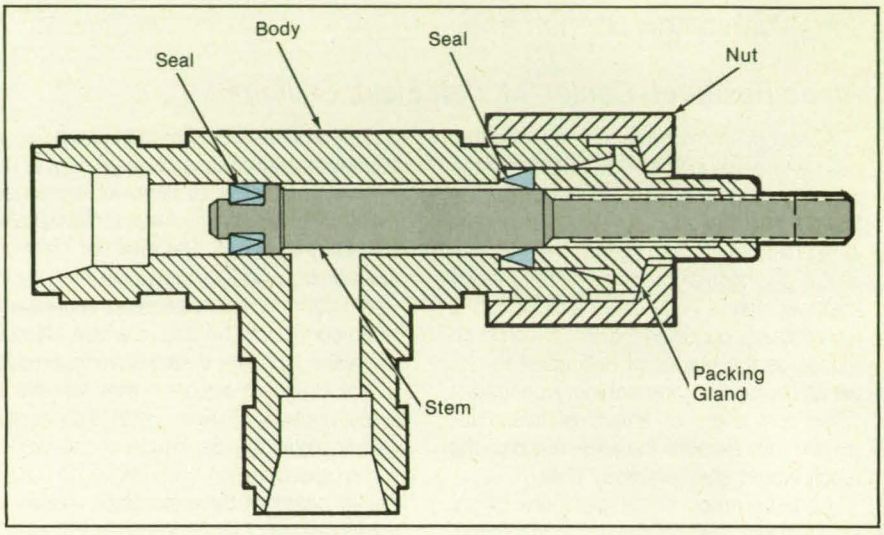
The valve provides trouble-free isolation under typical operating conditions.

Lyndon B. Johnson Space Center, Houston, Texas

A lightweight right-angle valve isolates a pressurized liquid or gas stream from a vacuum over a wide range of temperatures from ambient down to cryogenic. The valve is sized to fit tubes of the types ordinarily used in cryogenic equipment. Unlike prior valves designed for use with tubes, this one maintains isolation, without need for manual adjustment of its packing gland as pressure and temperature vary from medium vacuum [10^{-7} torr (about 10^{-5} Pa)] at −100 °F (−73 °C) to 150 lb/in.^{2} (about 1 MPa) at 70 °F (21 °C).

The mass of the valve is less than 60 grams. The valve (see figure) is made of off-the-shelf parts and a few simple custom-machined parts.

This work was done by Richard B. Calhoun of Lockheed Engineering & Sciences Co. for **Johnson Space Center**. *For further information, Circle 17 on the TSP Request Card.*
MSC-21889



This **Lightweight Right-Angle Valve** is designed to provide a tight seal (without manual readjustment of its packing gland) over a wide range of temperatures and pressures. It can be made partly of commercial (Swagelok® or equivalent) components.

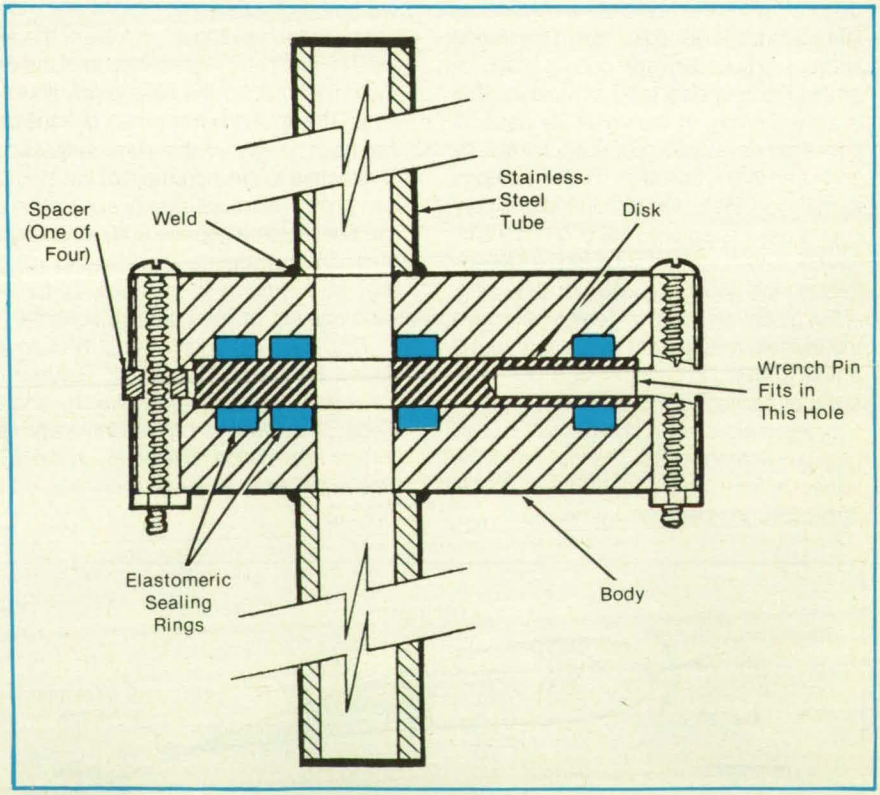
Disk Valve for Cryogenics

This simple unit remains leaktight over a wide range of pressures and temperatures.

Lyndon B. Johnson Space Center, Houston, Texas

The lightweight disk valve illustrated in the figure is designed to have dimensions and capabilities similar to those of the valve described in the preceding article, "Lightweight Right-Angle Valve for Cryogenics" (MSC-21889). This disk valve is designed to operate over the same range of temperatures and pressures as that of the lightweight right-angle valve; to fit tubing of the same sizes; and to remain leaktight under changing conditions, without need for manual readjustment of a packing gland. Also like the right-angle valve, this one weighs less than 60 g and can be made relatively inexpensively from some commercial and a few simple custom-machined components.

This work was done by Richard B. Calhoun of Lockheed Engineering & Sciences Co. for **Johnson Space Center**. *For further information, Circle 16 on the TSP Request Card.*
MSC-21888



External Tubing Is Attached to stainless-steel tubes that extend from opposite faces of the body of the disk valve. The disk contains an eccentric hole: shown here in the "open" position, it can be rotated to the "closed" position by use of a wrench pin inserted in a radial socket. Rings in the circular grooves maintain the seal.

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Measuring Tollmien-Schlichting Instabilities in Laminar Flow

Surface-mounted hot-film sensors detect T–S waves.

Langley Research Center, Hampton, Virginia

One of the primary objectives of today's research in laminar flow is to explore the limits of wing sweep, Reynolds number, mach number, and pressure gradients for which laminar flow can be achieved and maintained on modern airplane surfaces in typical operating environments. Past flight-research measurements of transitions in laminar flow focused on the locations of transitions without exploring the dominant instabilities responsible for initiating the transition process. Of importance to modern flight research in laminar flow is the ability to understand the specific causes of laminar-to-turbulent boundary-layer transitions. A recent NASA flight experiment was conducted to evaluate surface-mounted hot-film sensors designed to detect Tollmien–Schlichting (T–S) instability in the boundary layer in flight.

The flight experiment was conducted on a Lear Model 28/29 business jet airplane operated by NASA at Langley Research Center for flight research in the reduction of drag. The range of operating conditions includes mach numbers up to 0.81, maximum unit Reynolds numbers up to 2.65×10^8 per foot (8.69×10^8 m^{-1}), and maximum altitudes up to 51,000 ft (15.5 km). The wing on this airplane incorporates a non-production, modified airfoil section. The wing has a very smooth surface that is well-suited to research on laminar flow.

Nine hot-film sensors were mounted on the surface of the wing for this experiment. Each sensor consisted of nickel film deposited on a substrate of polyimide film. Each of the hot films was operated in a constant-temperature (uncompensated) mode. The anemometer electronics included the hot-film sensor as one side of a Wheatstone bridge circuit and an amplifier with internal programmable gain and filtering. In addition, each signal was externally amplified with a fixed gain prior to recording.

Three sensors were located at 20, 30, and 40 percent of chord with appropriate staggering to prevent neighboring sensors from causing premature turbulent contamination.

The flight test was conducted at mach 0.79 and an altitude of 39,000 ft (11.9 km). The data were obtained by performing slow decelerations and accelerations, which caused the transition to move across the 20-, 30-, and 40-percent-of-chord stations. Data were analyzed when the signal was still laminar but just prior to the first turbulent bursts preceding transition.

A two-dimensional linear stability analysis of the laminar velocity profiles was calculated by both the SALLY (Stability, Analysis, Local, Linear, and Incompresible) and the COSAL (Compressible Stability Analysis) computer programs. For the T–S predictions, the data were initially analyzed by use of the SALLY over a wide range of frequencies at zero wave angle. After the most amplified frequency was identified, COSAL calculations were made for that frequency over a range of wave angles. The analytical effort showed that the hot films correctly measured the amplified T–S frequency range. Future flight tests requiring the determination of T–S disturbance frequencies could rely on hot-film data without requiring analytical predictions.

The new technique should have considerable value in applied research aimed at extending the regions of natural laminar flow on an aircraft. It aids research into the mechanisms leading to transition from

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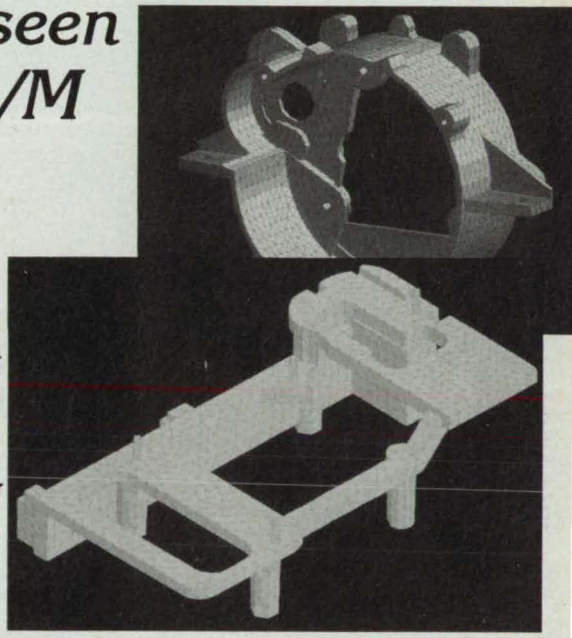

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laminar to turbulent boundary layers. The new technique makes it practical to take measurements in many locations on a wing surface for tests in flight. This technique would be useful in studying transitions in such flow as those in pipes, ducts, channels, compressors, and diffusers.

This work was done by Cynthia C. Lee, Gregory S. Manuel, and John P. Stack of **Langley Research Center**. *For further information, Circle 63 on the TSP Request Card. LAR-14132*

Single-Tip Probe Senses Pressure or Temperature

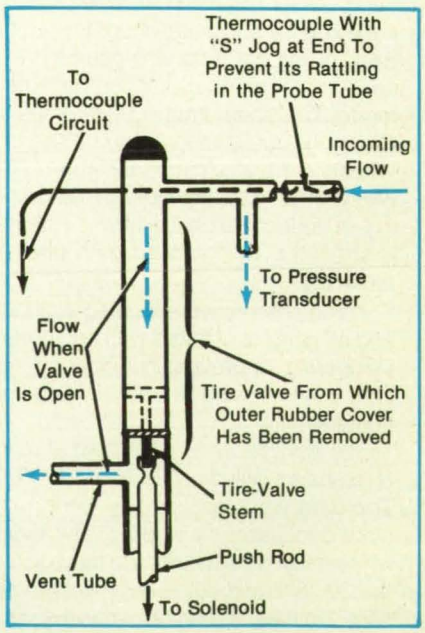
A valve is actuated remotely to switch between pressure- and temperature-sensing modes.

Lewis Research Center, Cleveland, Ohio

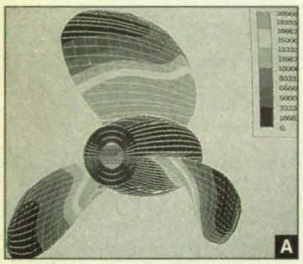
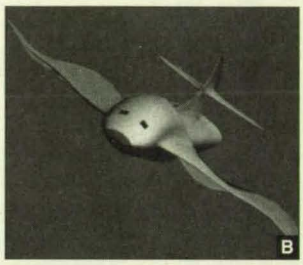
A single-tip probe designed for use in a supersonic wind tunnel can be switched to sense pressure or temperature. Heretofore, it has been necessary to use separate probes to measure pressure and temperature and, if using both probes simultaneously, to place them sufficiently far apart across the flow to prevent interference (principally, via propagation of shock waves) between them. The new single-tip probe senses temperature or pressure at the same point in the flow. Furthermore, in the sense that it can be switched rapidly between pressure- and temperature-measuring modes, it provides nearly simultaneous measurements of both pressure and temperature at that point. It is not necessary to stop a wind-tunnel test and exchange probes to change between pressure and temperature measurements.

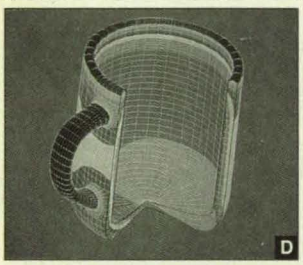
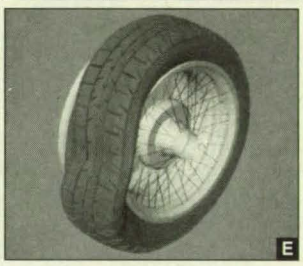
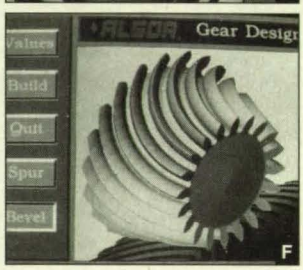
The probe (see figure) includes a small valve like the valves used in bicycle and automotive tires. The valve (called a "Schraeder valve") is actuated by a push rod driven by an electric solenoid. When the valve is in its spring-loaded, normally closed condition, the flow in the probe tubes is blocked, and the pressure of the outside oncoming flow is transmitted via a tube to a standard pressure transducer located elsewhere. When the solenoid is energized, the rod pushes the valve open, allowing some flow in the probe tube. This flow aids the thermal response of a thermocouple that is mounted in the probe tube and that serves as the temperature transducer.

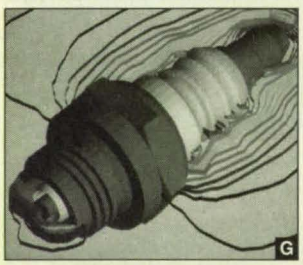
This work was done by Paul Trimarchi of **Lewis Research Center**. *For further information, Circle 95 on the TSP Request Card. LEW-15296*



The Tire Valve Is Opened or Closed by the push rod and solenoid. In the open position, the flow past the thermocouple enables measurements of temperature. In the closed position, flow is blocked and pressure in the probe backs up to a pressure transducer.



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Fail-Safe Pressure Plug

This protective plug resists slowly built-up pressure or automatically releases itself if pressure rises suddenly.

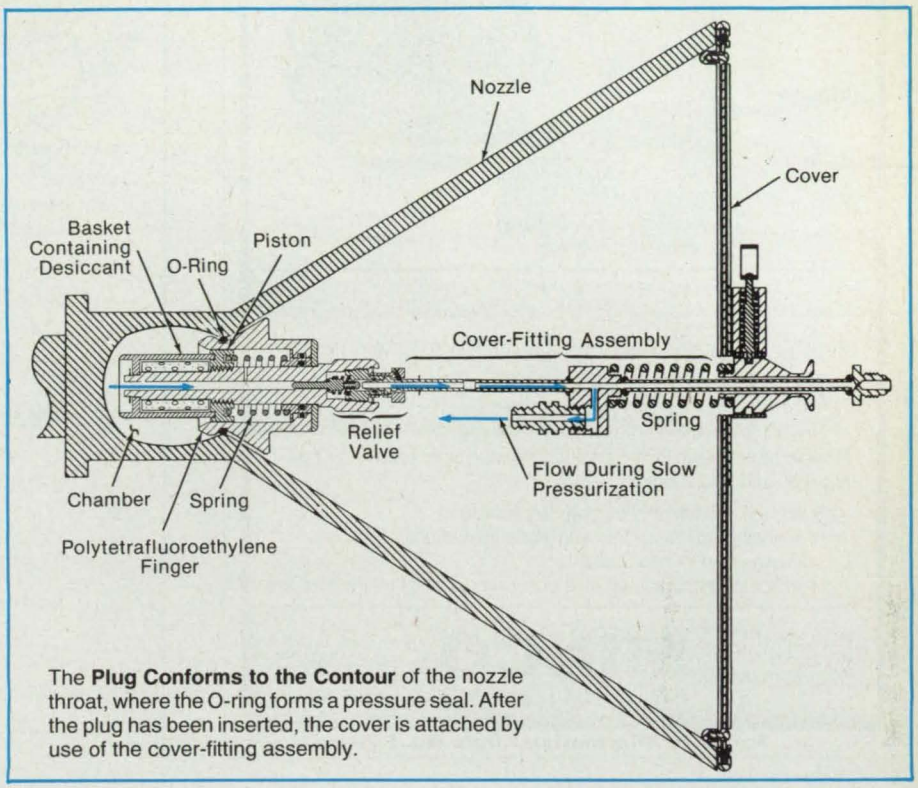
Lyndon B. Johnson Space Center, Houston, Texas

A protective plug seals out moisture at pressures ranging from 50 μm of mercury (6.7 Pa) to 200 lb/in.^{2} (1.4 MPa). The plug is designed to seal the throat of the 38 Reaction Control Thrusters on the Space Shuttle and thereby protect internal components from corrosion. Modified versions might be useful in protecting engines, pumps, reaction vessels, and other industrial equipment during shipment and maintenance.

The plug withstands slow pressurization up to 200 lb/in.^{2} (1.4 MPa) so that thrustors can be purged and pressurized during maintenance. However, a rapid increase in pressure blows out the plug at 60 lb/in.^{2} (0.41 MPa). Thus, if a plug is inadvertently left in at the start of a mission, it will be expelled as soon as a thrustor fires in normal operation. The plug also contains a relief valve that vents at 8.5 lb/in.^{2} (59 kPa) to prevent a buildup of internal pressure from heating or leakage from propellant valves.

The retaining element of the plug is a polytetrafluoroethylene (teflon) housing that has been slotted to form flexible fingers (see figure). When a piston inside the plug is pulled (to the right in the figure) by a bolt, the fingers flex inward so that they pass through the throat of the thrustor nozzle. When the bolt is released, a spring pushes the piston to its original position. The piston expands the fingers outward so that they lock the plug into the throat. A special tool is used to insert and remove the plug. A handle on the tool is rotated to push and pull the piston. The outer end of the nozzle is fitted with a protective cover after the plug has been installed.

The teflon fingers are sized so that they fit the throat without pressing hard against it. The only loads the fingers carry are from pressure in the thrustor chamber and the spring loading of the outer cover. This design feature reduces the cold flow that teflon parts typically exhibit when loaded for long times. The plug includes a basket that holds silica gel, a desiccant, on its interior end. The gel removes residual moisture from the air remaining in the chamber.



The **Plug Conforms to the Contour** of the nozzle throat, where the O-ring forms a pressure seal. After the plug has been inserted, the cover is attached by use of the cover-fitting assembly.

A small orifice through the plug links the thrustor chamber to the volume behind the piston. Thus, when the chamber is slowly pressurized for testing or maintenance, a counterpressure builds up behind the piston. In this slow-pressurization mode, the piston is not pushed back to release the fingers until the pressure reaches 222 lb/in.^{2} (1.53 MPa). If, however, the chamber is rapidly pressurized — when it is fired — there is no opportunity for a counterpressure to build up. At 60 lb/in.^{2}, the rapidly rising pressure pushes the piston back, causing the fingers to be retracted, and the pressure then expels the plug. In addition, if the pressure remains above 100 psi (0.7 MPa) for a long time, the plug slowly moves out of the throat by cold flow of the teflon fingers; eventually, the seal is broken, and the pressure is thereby released.

This work was done by Paul A. Svejkovsky of Lockheed Engineering & Sciences Co. for **Johnson Space Center**. *For further information, Circle 23 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 20]. Refer to MSC-21898.

Six-Degree-of-Freedom Magnetic Vibration Isolator

Feedback control provides a soft mount and damping of vibrations.

Marshall Space Flight Center, Alabama

An active magnetic suspension system centers an inner structure (and a mass mounted on it) in position and orientation with respect to the principal Cartesian coordinate axes of a base or outer structure, which is stationary with respect to a building or vehicle. The system helps to isolate the suspended mass (e.g., a scientific instrument) from vibrations of the building or vehicle. The system is designed primarily to isolate a 500-kg experimental apparatus from vibrations of a spacecraft, but can also be used on Earth, provided that its z axis is vertical and the system is assisted by a low-stiffness vertical spring that, in the steady state, holds up the inner structure at the nominal vertical position.

The system (see Figure 1) includes four actuators, which are located on the $+x$, $-x$, $+y$, and $-y$ sides of the inner structure. Each actuator includes two partly

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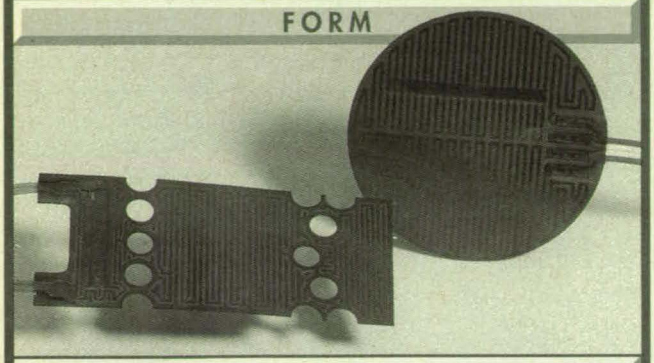

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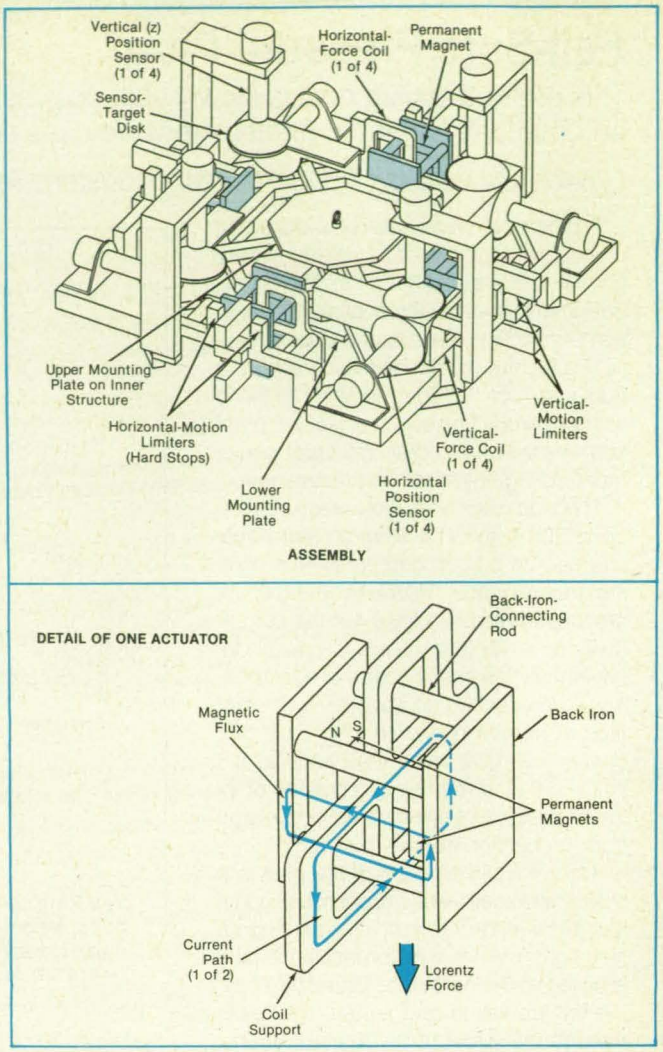


Figure 1. The **Prototype Vibration Isolator** includes Lorentz-force actuators, which are superior to other magnetic actuators in this application because they offer stable, approximately linear response.

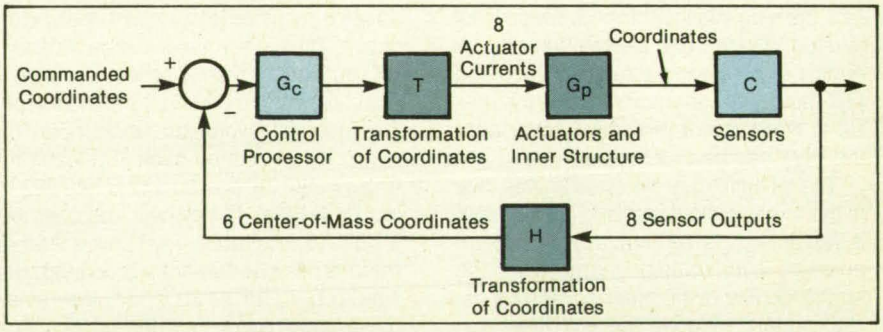


Figure 2. **Position Feedback** from eddy-current sensors is processed into actuator currents.

overlapping electromagnet coils mounted on the outer structure, plus a pair of permanent magnets and associated back irons mounted on the inner structure. The electromagnet coils are sized, shaped, and positioned so that an L-shaped portion consisting of a horizontal leg of one coil and a vertical leg of the other coil lies in the gap between the permanent magnets. In the case of the actuator on the $+x$ or $-x$ face, the permanent-magnet field is nominally along the x axis. Current can be supplied to either or both coils, so that the current in the L-shaped portion in the magnetic field can have components in both the y and z directions. The interaction between the x magnetic field and the y (or z) current results in a Lorentz force in the z (or y) direction.

The actuators are somewhat redundant in that the four actuators produce eight independently controllable forces — two more than are needed for control in six degrees of freedom. The contribution of this redundancy to the cost and complexity of the system is offset by the simplicity of the Cartesian coordinate system and the consequent simplification of the control computations.

During operation, the inner and outer structures do not make contact. The clearances between the electromagnet coils and the back-iron-connecting rods allow strokes of slightly more than ±1 cm along the principal axes, and lockable set screws serve as hard stops that limit the strokes to ±1 cm. This stroke provides isolation at frequencies $\gtrsim$ 0.04 Hz.

The position and orientation of the inner structure are measured by noncontact eddy-current sensors mounted on the outer structure. These sensors are part of a digital feedback control system (see Figure 2). The outputs of the sensors are digitized, then transformed into center-of-mass coordinates, in which the motions in the six degrees of freedom are uncoupled from each other. A control processor implements six single-input/single-output lead/lag control algorithms, and the six resulting control outputs are subjected to another coordinate transformation to convert them into commands for the eight actuator currents. These commands are fed to amplifiers, which supply the currents to the electromagnet coils.

This work was done by Michael J. Gerver, Ralph C. Fenn, Timothy J. Hawkey, and Lawrence A. Ormord of SatCon Technology Corp. for **Marshall Space Flight Center**. *For further information, Circle 94 on the TSP Request Card.* *MFS-26170*

Robot Would Reconfigure Modular Equipment

Human technicians would not have to enter a hostile environment.

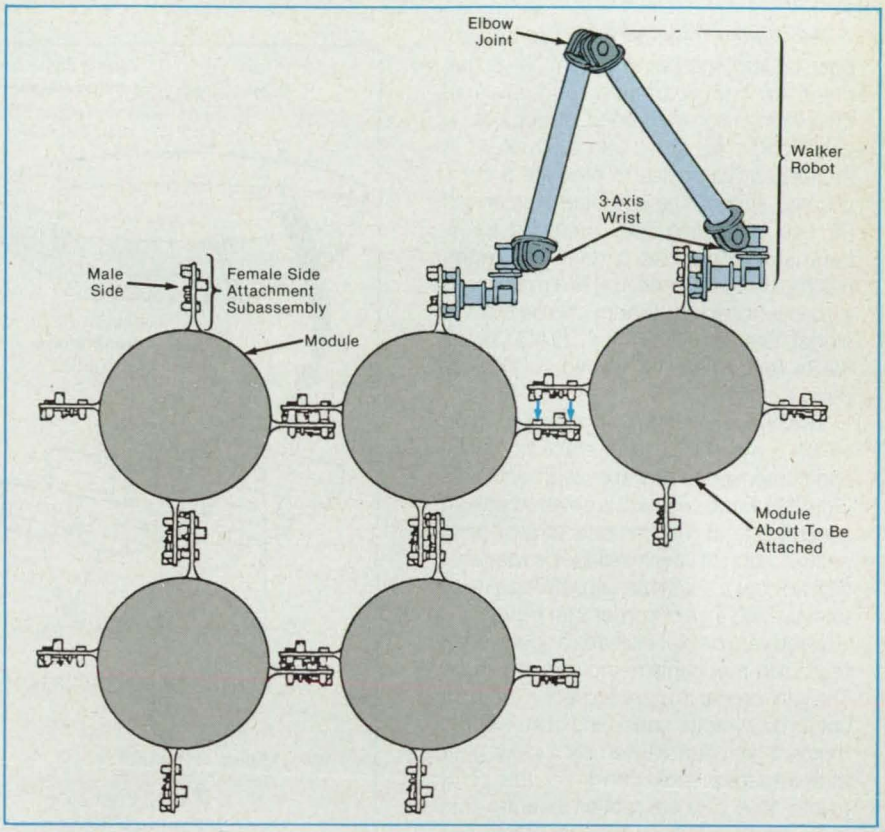
Goddard Space Flight Center, Greenbelt, Maryland

Special-purpose sets of equipment, packaged in identical modules with identical interconnecting mechanisms, would be attached to or detached from each other by a specially designed robot, according to a proposal. In the original intended application, the modules would be those of a facility or station in outer space, and the robot reconfiguration scheme would make it unnecessary for astronauts to venture outside a spacecraft or space station. The concept may also prove useful on Earth; for example, in the assembly, disassembly, or reconfiguration of equipment in such hostile environments as underwater, near active volcanoes, or in industrial process streams.

In the example of the figure, the modules would be cylindrical, and each module would have four attachment subassemblies spaced equally around the circumference. Each attachment subassembly would consist of a flange having male fluid, electrical, and force-carrying connectors on one side. The male side of any attachment subassembly could mate with the female side of an attachment subassembly on any other module. As shown in the figure, there would be at least two rows of modules so that there would be redundant paths for passing force, fluid, data, and power. Also, any critical modules would be duplicated to provide redundancy. These redundancies would allow the robot to remove any single module without causing loss of operation of the still connected modules.

To guide the robot when it positions modules to be connected, the male sides of the attachment subassemblies would be equipped with a TV camera, and the female sides with an optical target. The force-carrying connector would consist of self-aligning kinematic mounts. Once the robot brought the male and female sides of two attachment subassemblies into contact, a motor on the male side would drive a wedge between rollers on the two sides in manner that would drive the kinematic mounts together, locking the two attachment subassemblies, as well as causing their electrical and fluid connectors to mate.

The robot would be a walker-type manipulator having two sets of three-axis wrist joints connected by an elbow joint. Each joint would include the motor, gearing, and sensors for position and torque. Each end of the robot would be equipped with an end effector configured like the male side of an attachment subassembly, so that the end effector could lock itself to the female side of any attachment subassembly. The robot would be controlled by a computer that would allow it to function autonomously or under supervision of a remote operator. The robot would walk along a set of connected modules by making the end effectors successively grasp and release attachment subassemblies. If one of the robots end effectors were dedicated to carrying a module, then the male side of one of the carried-module attachment subassemblies would act as the second robot end effector for the purpose of walking.



The **Two-Arm Walking Robot** would connect and disconnect modules, operating either autonomously or under remote supervision. The robot would walk along a row of connected modules by grasping successive attachment subassemblies in a hand-over-hand motion.

This work was done by Lloyd R. Purves of **Goddard Space Flight Center**. *For further information, Circle 24 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC-13408.

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More About the Farley Three-Dimensional Braider

Yarns can be incorporated at arbitrary braid angles.

Langley Research Center, Hampton, Virginia

The Farley three-dimensional braider, now undergoing development, is a machine for the automatic fabrication of three-dimensional braided structures. It can incorporate yarns into a structure at arbitrary braid angles to produce a complicated shape. The machine is intended for use in making fiber preforms for fiber/matrix composite parts — for example, multiblade propellers. [The machine is also described in "Farley Three-Dimensional Braiding Machine" (LAR-13911), *NASA Tech Briefs*, Vol. 15, No. 3, (1991,) p. 60].

The braider includes a braiding surface, which is a partial or full surface of revolution composed of movable segments (see Figure 1). Each segment is covered with an assemblage of mechanisms called "pivot points," each of which includes a rotatable disk holding a shaft that constitutes a track along which a yarn carrier can travel.

Each yarn carrier includes a spool with a rewinding mechanism and a fault sensor. The yarn carrier is propelled along the pivot points by a tractor consisting of an electric motor, a gear-head assembly, a drive gear that engages rack gears on the pivot points, and a linear-motion bearing that engages the shafts on the pivot points (see Figure 2).

The yarn carriers move across the braiding surface and between segments by moving from one pivot point to another. The direction of travel of each yarn carrier is controlled by rotating, to the appropriate orientations, the pivot points along its trajectory. The direction of travel of a yarn carrier can be changed by stopping at a designated pivot and rotating that pivot point to the desired new orientation.

The braiding surface also holds fixed tubes to feed nonbraiding (fill) yarns. These fill yarns are used as unidirectional fibers in the preform; e.g., fibers that lie parallel to the braiding axis of a preform.

The braider includes a material-takeup system, which is customized for the unique geometry of the preform. This system maintains a constant distance between the braiding plane on the preform and the segmented braiding surface. This makes it possible to control the braid angles of the yarns accurately and facilitates the maintenance of tension on the braiding yarns.

A computer and associated electronic equipment coordinate the multiple simultaneous motions of the braiding surfaces, pivot points, yarn carriers, and the material-takeup system. The multiplicity of possible motions gives the designer great flexiblity in assigning braid angles and other parameters to the yarns in the structure.

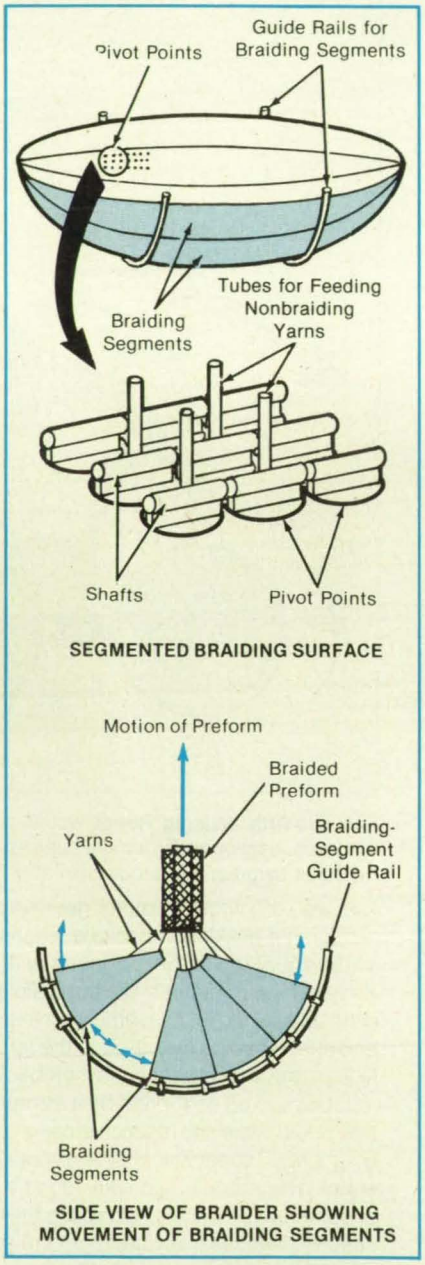


Figure 1. The **Braiding Surface** includes movable braiding segments containing pivot points, along which the yarn carriers travel during the braiding process.

This work was done by Gary L. Farley of **Langley Research Center**. *For further information, Circle 1 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14047.

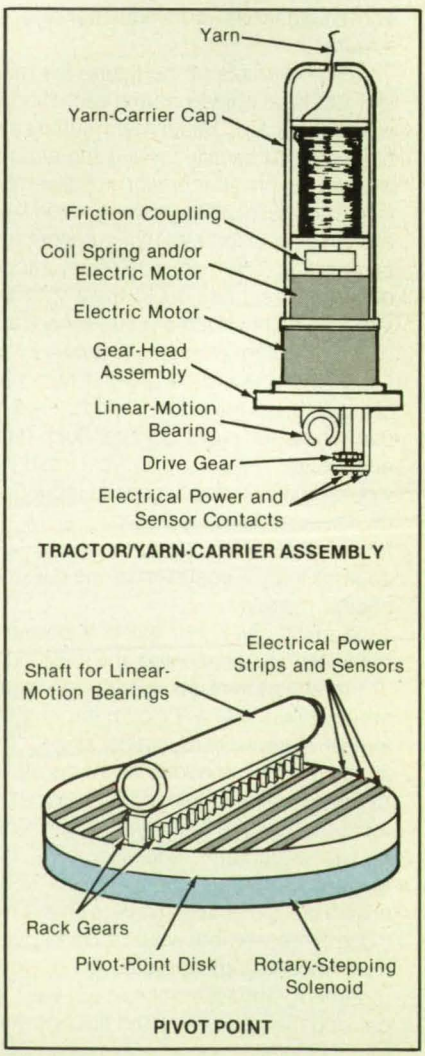


Figure 2. A **Yarn Carrier** travels along a sequence of pivot points as the braiding segments move. The combined motions position the yarns for braiding onto the preform.

Apparatus Splits Glass Tubes Longitudinally

Tubes are split into half cylinders by the hot-wire/thermal-shock method.

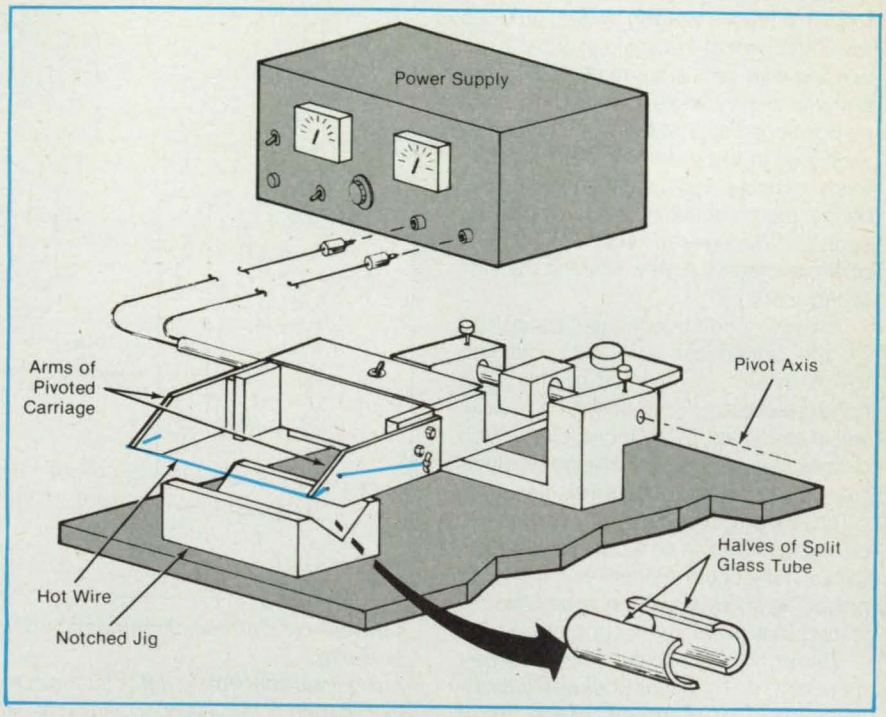
John F. Kennedy Space Center, Florida

The apparatus shown in the figure splits glass tubes in half longitudinally by the well-known hot-wire/thermal-shock method. A tube to be cut is placed on a notched jig in the apparatus.

A nichrome wire is stretched between the arms of a pivoted carriage and oriented parallel to the notch. The wire is heated by electrical current while it rests on the tube. After heating for about 1 minute for each millimeter of thickness of glass, the tube is quenched in water and is split by the resulting thermal shock.

The apparatus has been used to split tubes in sizes ranging from 3/8 in. (9.5 mm) in diameter by 1 in. (25.4 mm) long to 1½ in. (38.1 mm) in diameter by 4 in. (102 mm) long.

This work was done by Ernest Shaw and Robert O'Neil Manahan of Lockheed Space Operations Co. for **Kennedy Space Center**. *For further information, Circle 52 on the TSP Request Card.*
KSC-11547



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Adjustable Bracket for Entry of Welding Wire

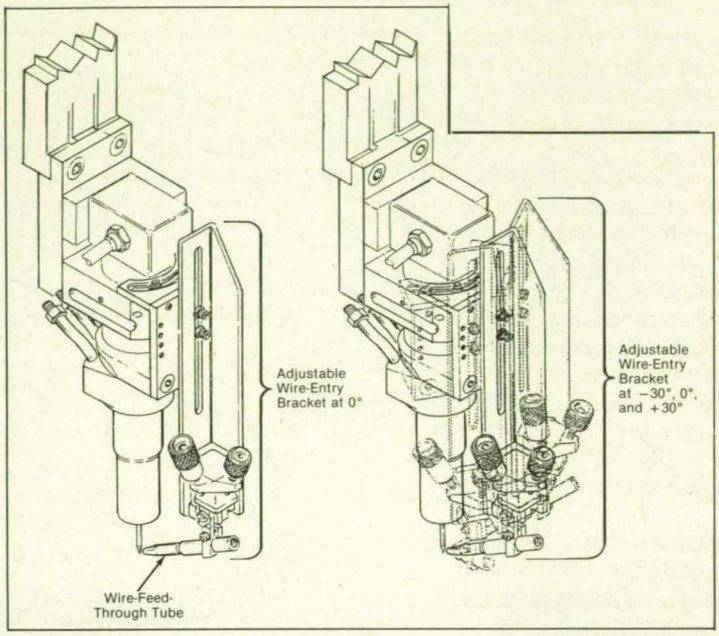
The angle of the bracket can be adjusted to give a clear view.

Marshall Space Flight Center, Alabama

The wire-entry bracket on a welding torch in a robotic welding system provides for adjustment of the angle of entry of the welding wire over a range of ±30° from a nominal entry angle. The wire can thus be positioned so that it does not hide the weld joint in the view of the through-the-torch computer-vision system that is part of the robot-controlling and -monitoring system. ("Through the torch" is something of a misnomer; the view is along the axis of the torch.)

The wire-feed-through tube is mounted on the adjustable wire-entry bracket, which, in turn, is mounted on the torch head (see figure). The bracket can swivel within the limits of an arced slot, which defines the ±30° angular range on either side of the nominal central angle.

The swiveling bracket could also be used on a nonvision torch on which the wire-feed-through tube could interfere with the workpiece. The angle would simply be changed to one that gives sufficient clearance.



This work was done by Jeffrey L. Gilbert and David A. Gutow of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29837.

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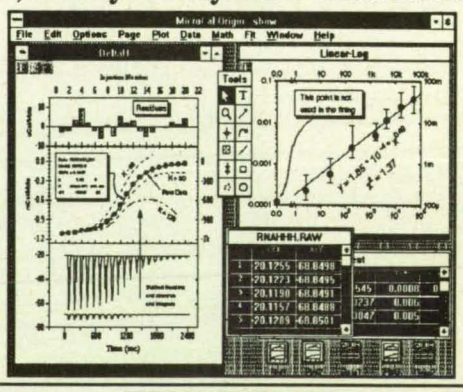

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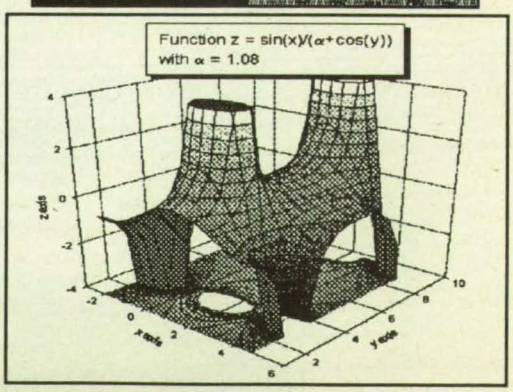

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Separation of Metals Bonded With Two-Sided Tape

Ultrasonic cleaning in hot kerosene enables separation without damage.

Langley Research Center, Hampton, Virginia

A procedure has been developed to separate, without pulling, bending, or prying, objects that have been temporarily bonded together with two-sided tape. The need for the technique arose as follows:

A National Institute of Standards and Technology test specimen made of 200-series nickel, 0.050 in. (1.3 mm) thick, was to be lapped to a flatness of 0.0000 to 0.0002 in. (0 to 5 μm) prior to vacuum brazing. The specimen had to be bonded to a block of 17-4 PH stainless steel to hold it for the lapping procedure. In preparation for bonding, the specimen was ground flat on one side. Then it was bonded to the block by use of two-sided tape. The thinness and softness of the nickel specimen made it vulnerable to bending, thereby necessitating the development of a technique to remove it from the block after lapping, without bending it or otherwise degrading its flatness.

Because of unacceptable results obtained by use of a typical hot kerosene bath, the new procedure was introduced. Specimens bonded to blocks were placed in kerosene in an ultrasonic cleaning unit and the temperature of the kerosene was adjusted to 180 °F (82 °C). The parts separated, and all signs of adhesive were gone within minutes. The use of ultrasonics in this debonding procedure has made it possible to maintain gap tolerances of less than 0.0005 in. (13 μm).

The debonding procedure is simple. In a more systematic version of the procedure, the bonded objects to be separated are placed in a tank that is equipped with an ultrasonic transducer and that is large enough to hold and completely submerge the parts in kerosene. The kerosene is heated to a temperature between 180 °F (82 °C) and 220 °F (104 °C). The ultrasound is turned on before the parts have reached 170 °F (77 °C) to ensure that the kerosene penetrates between the pieces and starts to dissolve the adhesive. When the temperature of the parts has reached about 180 °F (82 °C), the parts can be removed from the kerosene and separated by sliding or pushing them apart. The nickel specimen (or other part of interest) is then cleaned in trichloroethane to remove kerosene residue. It is then placed in an ultrasonic cleaning unit with a cleaning solution and heated to 120±10 °F (49±6 °C) for 5 minutes. Finally, the specimen is rinsed thoroughly, first in deionized water, then in isopropyl alcohol. After drying with a hot-air gun, the specimen is ready for vacuum brazing.

The ability to remove tapes and protective papers, regardless of age, by use of this procedure has been proved. Four-month-old protective paper was removed from 6061 Al in 20 minutes at 150 °F (66 °C) with no adhesive residue. A 5-year-old protective paper was removed from Inconel 625* with little effort. The paper came off in 15 minutes. The removal of the adhesive, which had dried out completely, took an additional 20 minutes at 180 °F (82 °C). Masking tape comes off metals completely in less than 5 minutes at 150 °F (66 °C). This procedure is generally applicable in the removal of protective backing from metals as received, or in removing temporary bonding tape from metal specimens without damage to the specimens.

*"Inconel" is a registered trademark of the INCO family of companies.

This work was done by Michael L. Kelly of **Langley Research Center**. *No further documentation is available.*
LAR-14495

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Advancing-Front Algorithm for Delaunay Triangulation

Computational grids are generated from arbitrary nodal points.

Ames Research Center, Moffett Field, California

An efficient algorithm performs Delaunay triangulation to generate unstructured grids for use in computing two-dimensional flows. As used here, "unstructured" means specified in terms of arbitrarily located points (nodes). Delaunay triangulation solves the problem of which pairs of nodes to connect with straight-line segments so as to obtain an optimum tessellation of the grid area. The Delaunay triangulation of a given set of nodes is unique. In addition, it maximizes the smallest angle in the grid — a feature that is desirable in some applications.

Figure 1 illustrates the basic principles of Delaunay triangulation. Consider a plane containing some nodes. The plane can be divided into polygonal areas, called "Dirichlet regions," each of which is the locus of all points that are closer to a given node than to any other node. Each vertex of a polygon is equidistant from several (usually three) nodes. A circle centered on the vertex is drawn through the (usually three) nodes.

This circle is called the "circumcircle," and unless one or more of the nodes of the circumcircle lie on the boundary of the grid, no other node lies within the circumcircle. Provided that there are three nodes on the circumcircle, the nodes can be connected with straight lines to form a triangle. (As explained subsequently, a slightly different procedure must be used when the number of nodes on the circumcircle exceeds three). This process is repeated until every node is connected by straight lines, thereby constructing the grid out of triangles.

Figure 2 illustrates how the algorithm performs the Delaunay triangulation, starting from a line of nodes that defines a boundary and advancing across a field of nodes. The algorithm involves the following steps for each pair of adjacent nodes along the boundary:

1. Find any node on the correct side of the boundary.
2. Construct a circle through this node and the two nodes in question on the boundary.
3. Find the node (if any) closest to the center of the circle. (Do not count nodes on the circle or on the wrong side of the boundary.)
4. If no node was found in step 3, then the node found in step 1 is the correct one to use in the Delaunay triangulation. If a node was found in step 3, then repeat step 2, using this node instead of the node found in step 1.
5. Repeat the foregoing steps at all points along the boundary. The edges of the Delaunay triangles thus constructed can be regarded as a new boundary or front.

By performing steps 1 through 5 along the new boundary, one causes the front to advance. The process is repeated until all the nodes are incorporated into the grid.

It can happen that four points lie on the circumcircle. This situation typically occurs when a mesh-generating algorithm has specified nodes that lie within roundoff error of a perfect rectangle. (Redundancies of higher order could occur in principle but are rare in practice.) In such a case, two points present themselves as candidates to be the next point incorporated into the grid, and selection of the wrong one could result in crossed gridlines, which are not allowed. The algorithm selects whichever one of the two candidate nodes lies on the correct side of the advancing boundary.

Once a grid has been generated, one can optionally call upon an additional subalgorithm that removes diagonal lines from quadrilateral cells that are nearly rectangular. The resulting approximately rectangular grid can reduce the cost per iteration of a flow-computing algorithm.

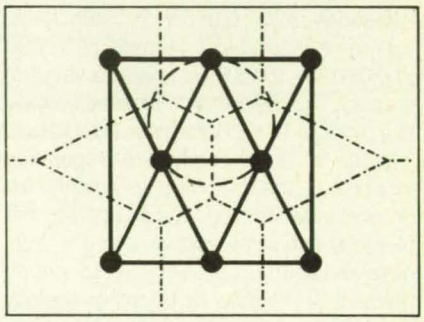


Figure 1. **Delaunay Triangles** are constructed by connecting nodes with straight lines according to rules described in the text. The large dots denote nodes. The solid lines denote Delaunay triangles. Dotted lines indicate borders of Dirichlet regions. The dashed circle through three nodes is a circumcircle.

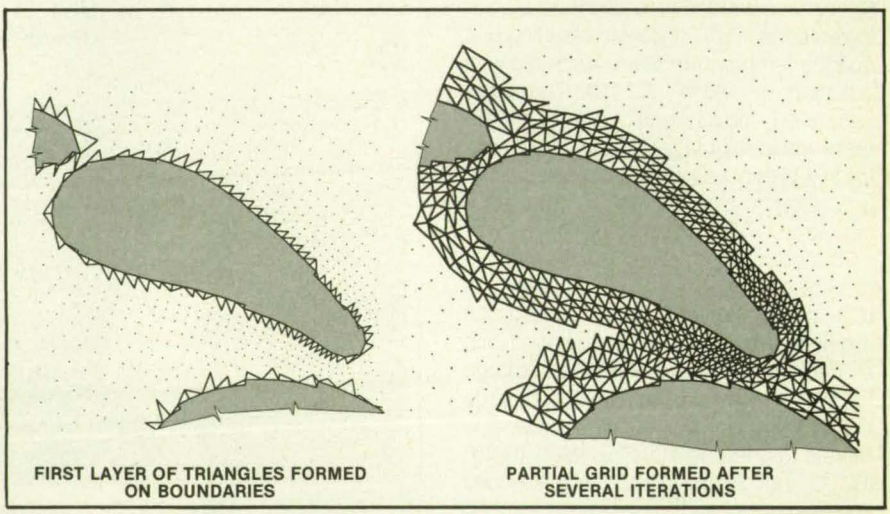


Figure 2. An **Advancing-Front Delaunay Triangulation** is shown at two different stages of completion.

This work was done by Marshal L. Merriam of **Ames Research Center**. *Further information may be found in AIAA paper 91-0792, "An Efficient Advancing Front Algorithm for Delaunay Triangulation."*

Copies may be purchased [prepayment required] from AIAA Technical Information Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.

ARC-13092

Algorithm for Enlargement of Digitized Images

DIEBRA synthesizes higher spatial resolution better than do prior algorithms.

NASA's Jet Propulsion Laboratory, Pasadena, California

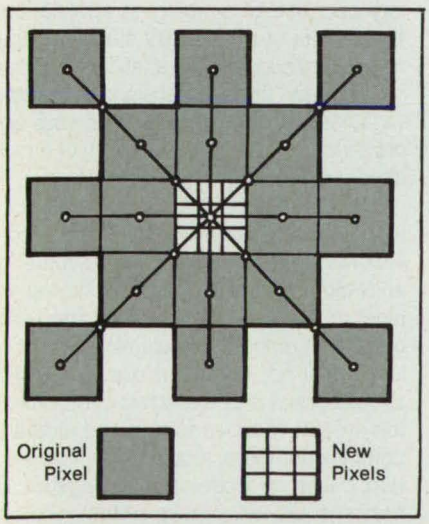
The Digital Image Enlarging Balanced Reconstruction Algorithm (DIEBRA) enlarges a digitized image composed of square pixels in such a way as to make the image look more like the real scene. If a digitized image is merely expanded to larger pixels or groups of pixels by use of a simple scale factor, the resulting larger squares, which correspond directly to the original pixels, lend an appearance of blockiness. DIEBRA synthesizes the enlarged image at a greater number of pixels, smoothing out the blockiness while providing resolution finer than that of the original pixels and, therefore, closer to that of the scene.

Prior techniques for reduction of blockiness and partial reconstruction of high-resolution image data have typically involved interpolation between pixels as though the pixels were point sources, followed by resampling of the interpolated image data at the higher resolution. Such techniques smooth out the blockiness and give the appearance of higher resolution, but the variances in the local brightness of the resulting images are smaller than those of the corresponding real scenes, and the resulting images exhibit only marginal correlation with true high-resolution imagery.

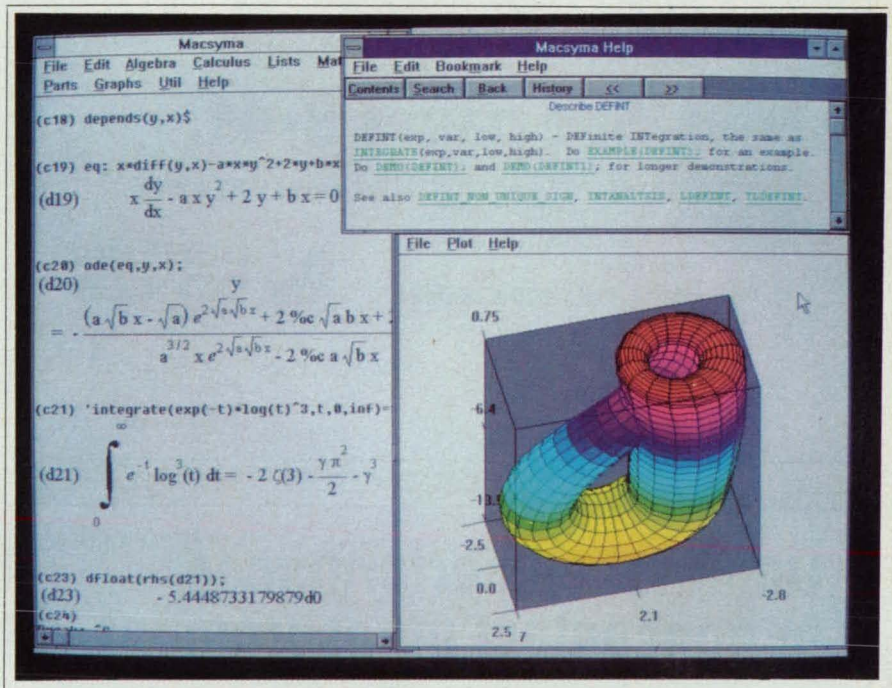
DIEBRA is based on a more-realistic treatment of pixels, not as points but as areas that represent spatial-resolution elements or fields of view of the imaging instrument. In this treatment, the brightness of each picture element is understood to be the brightness in the scene averaged over the field of view or resolution element with weighting by the point-spread and/or other response function of the instrument. Lacking information on the response function of the instrument, one can also obtain adequate results by assuming a non-weighted averaging over each original pixel and attempting to recover the high-resolution imagery by use of a square-wave filtering kernel.

The prototype version of DIEBRA enlarges the image to 3 × 3 times the original number of pixels. A 5 × 5-original-pixel reconstruction kernel (see figure) is moved across the image in jumps between centers that correspond to those of the original pixels. At each jump, polynomial fits are performed along the horizontal, vertical, and diagonal lines through the center, and only the interpolated values in the 3 × 3 new pixels in the central original pixel are retained.

Next, the interpolated brightness in the



The **Reconstruction Kernel**, shown here schematically, is moved across the image in increments that correspond to the original pixels.



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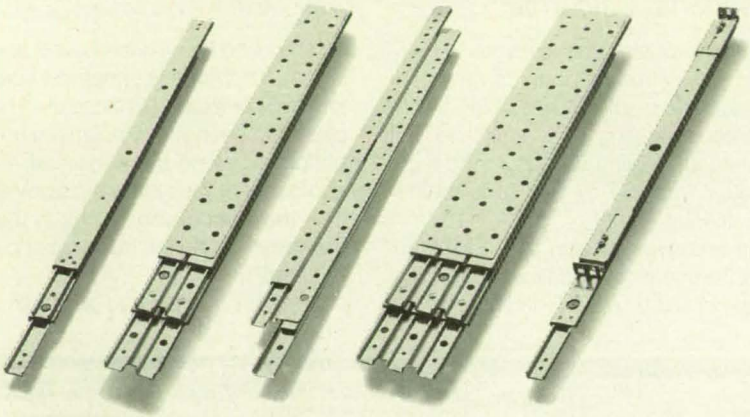

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central pixel of each new 3×3 block of pixels is increased or decreased and recursively interpolated until the mean brightness in the block matches that in the corresponding original pixel. This results in a reconstructed image that has greater contrast and that matches the real scene more closely than do images reconstructed by other techniques.

This work was done by William J. Rhea of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 35 on the TSP Request Card.*
NPO-18368

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Elements of Theory of Multidimensional Complex Variables

A system of multidimensional complex numbers and analytic functions thereof is described.

Two reports describe elements of a theory of multidimensional complex variables, with emphasis on three dimensions. Other algebras of hypercomplex numbers have been studied since the early nineteenth century in attempts to generalize the familiar theory of ordinary (two-dimensional) complex variables. Such attempts have been motivated largely by the importance and usefulness of analytic functions of ordinary complex variables in applications such as the calculation of two-dimensional potential flows, electrostatic fields, and other important physical phenomena. However, those algebras have not been completely satisfactory because of difficulty in application. The results of preliminary studies of the new theory suggest that analytic functions of the new three-dimensional complex variables should be useful in numerous applications, including representing of three-dimensional flows and potentials.

The first report introduces the general theory. A system of multidimensional complex numbers is defined with respect to an N-dimensional vector space having an algebra that is a commutative ring (with unity) with respect to multiplication but is in general not a division algebra. In the special cases of one and two dimensions, the system reduces to real and ordinary complex numbers, respectively. This system, based on a commutative algebra, is fundamentally different from other systems based on noncommutative, division algebras that generalize ordinary complex variables by way of quaternions.

Multiple Pages Intentionally Left Blank

The new three-dimensional system is a direct analog of the ordinary two-dimensional system of complex numbers and variables. Based on the new algebra, the report defines functions of a three-dimensional variable and develops significant elements of a theory of analytic functions of one three-dimensional variable. One notable element includes conditions of analyticity analogous to the well-known Cauchy–Riemann conditions of analyticity in two dimensions. It is shown how the parts of an analytic function of a three-dimensional variable provide components of solenoidal and irrotational harmonic vectors in three dimensions.

The second report presents further developments in the theory of analytic functions of a single three-dimensional variable and applies the theory to the representation of ideal flows. A three-dimensional velocity and a three-dimensional complex potential are defined in terms of analytic functions of a three-dimensional variable. Components of the complex potential are shown to be related to a three-dimensional velocity potential and three-dimensional stream functions.

It is shown that solenoidal and irrotational harmonic vectors of the types described in the first report are provided also by the vector terms of a certain trigonometric-series expansion of every elementary analytic function of a three-dimensional complex variable. ("Elementary analytic function," as used here, means an analytic function extended from the set of ordinary complex analytic functions.) The primary part (defined as the first real vector term in such an expansion) of every elementary analytic function of one three-dimensional variable represents an axisymmetric flow. Simple examples of such flows include a uniform stream, stagnation-point flow, source flow, flow due to a doublet (dipole), and flow over a sphere.

This work was done by E. Dale Martin of **Ames Research Center**. *To obtain copies of the reports, "Some Elements of a Theory of Multidimensional Complex Variables: Part I. General Theory" and "Some Elements of a Theory of Multidimensional Complex Variables: Part II. Expansions of Analytic Functions and Application to Fluid Flows," Circle 68 on the TSP Request Card.*
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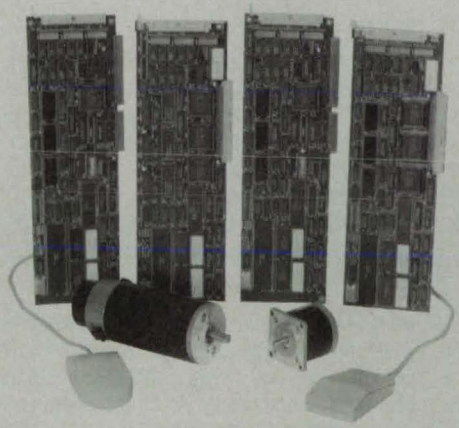

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For More Information Circle No. 663

Monolithic Continuous-Flow Bioreactors

Oxygen is provided through selectively permeable membranes.

NASA's Jet Propulsion Laboratory, Pasadena, California

Monolithic ceramic matrices that contain many small flow passages have been shown to be useful as continuous-flow bioreactors. The ceramic matrix containing the passages is made by extruding and firing a suitable ceramic, for example cordierite (made of alumina, magnesia, and silica) or steatite (made of magnesia and silica). The pores in the matrix provide an attachment medium for a film of cells and allow free movement of solution. The ceramic matrix material must be one that is not toxic to the micro-organisms to be grown in the reactor.

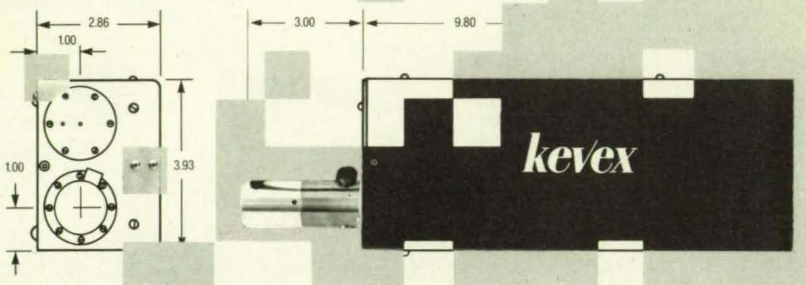
In a reactor of this type, liquid nutrients flow over, and liquid reaction products flow from, a cell culture immobilized in one set of channels while oxygen flows to, and gaseous reaction products (e.g., carbon dioxide) flow from, the culture in an adjacent set of passages. The cells live on the inner surfaces of the passages that contain the flowing nutrient and in the pores of the walls of those passages. They thus have ready access to the nutrients and oxygen in the channels. They generate the continuous high yield characteristic of immobilized cells, without the large expenditure of energy that would otherwise be incurred if it were necessary to pump the nutrient solution through a dense biomass as in bioreactors of other types.

A monolithic ceramic bioreactor can be configured so that the nutrient- and gas-flow passages are parallel or perpendicular to each other, for example (see figure). The walls of the gas-flow passages are coated with a hydrophobic (permselective) membrane; e.g., polypropylene film containing submicron pores. This film does not allow water or nutrients to pass but allows oxygen to flow from the gas passages through the ceramic and into the biofilm — the layer of cells immobilized in and on the ceramic.

Many important biological reactions tend to become limited by the difficulty of providing oxygen and would benefit from the plentiful supply of oxygen through the matrix walls. Among them are fermentation by *Acetobacter aceti* to produce acetic acid, production of antibiotic by *Penicillium chrysogenum*, and resolution of L-amino acids from racemic mixtures by *Trigonopsis variabilis*.

The selective-transfer property of the ceramic wall was demonstrated in experiments with murine–murine hybridoma cells, which produce a monoclonal antibody to human fibronectin. A cordierite slab containing passages was inoculated with the cells and sandwiched between porous polypropylene membranes. Nutrient medium was pumped through the passages in the porous ceramic while a gaseous mixture of air and carbon dioxide was pumped along both membranes.

In one experiment, the cell colony — initially 2.4×10^8 cells — grew exponentially for the first 100 hours, then more gradual-



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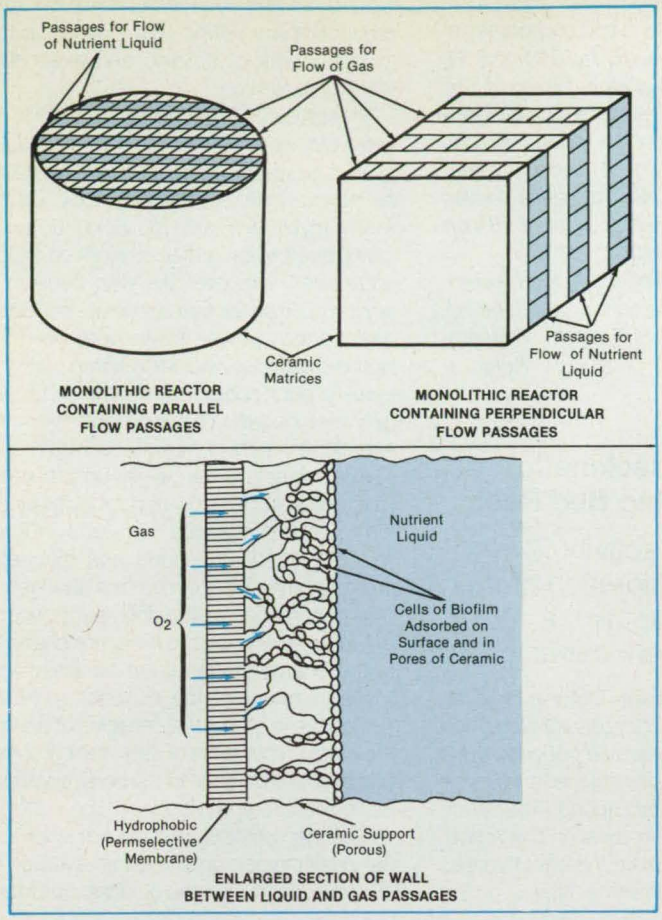

Rows of Nutrient-Liquid Passages are parallel or perpendicular to rows of gas passages. Cells grow on and in the walls between nutrient and gas passages. The cells have plentiful supplies of both nutrient solution and oxygen.

ly until, after 250 hours, it produced monoclonal antibody at a constant rate of 1.2 milligrams per hour. Because the cells continued to secrete antibody, oxygen must have been supplied to them in adequate quantity.

This work was done by Gregory Stephanopoulos, Julia A. Kornfield, and Gerald A. Voecks of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information Circle 4 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-18542, volume and number of this NASA Tech Briefs *issue, and the page number.*

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These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Water-Conserving Plant-Growth System

Nutrient solution is supplied only as utilized by seedlings.

A report presents further information about the plant-growth apparatus described in "Tubular Membrane Plant-Growth Unit." (KSC-11375), NASA Tech Briefs, Vol. 16, No. 2 (1992) page 113. The apparatus provides nutrient solution to the roots of seedlings

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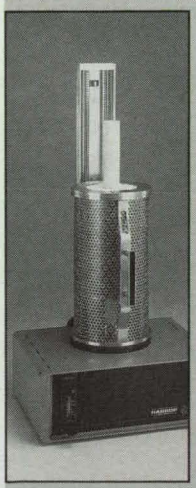

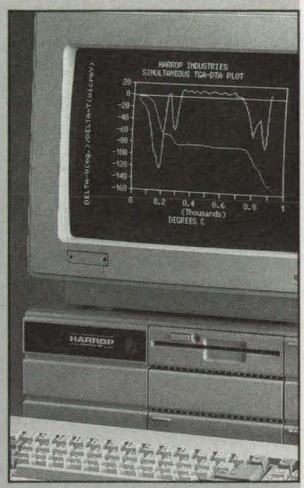

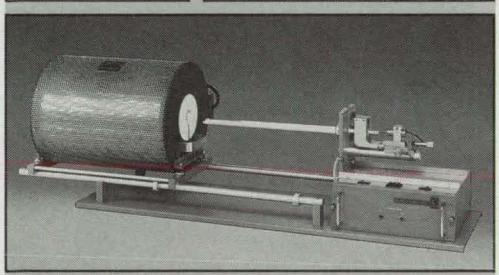

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without flooding. It also conserves water by helping to prevent evaporation from the plant bed.

The system includes plant-growth units that contain porous ceramic tubes and concentric seedling holders supported by slotted mesh frames. Several seedlings extend their roots into the airspace between the seedling holder and the ceramic tube, where they draw nutrient solution by capillary action of the solution through the tube.

Within each growth unit, two ceramic tubes are joined in parallel to inlet and outlet manifolds. A flexible-sided reservoir feeds the inlet manifold. A miniature gear pump draws the nutrient solution through the tubes and returns it to the reservoir. The pump creates a suction that is large enough to prevent the solution from leaking freely through the tubes but is small enough to allow the solution to be withdrawn through the pores of the tube by capillary action.

The seedling holders shade the roots and prevent them from drying. Each seedling holder is a sheet of polyethylene that is wrapped around a ceramic tube and braced in place by soft plastic foam. The seedlings grow upward between the flaps at the openings in the seedling holders on the upper sides of the tubes.

This device was developed for supporting plant growth in space. There also may be applications for growing plants with a minimum of water, such as in arid environments.

This work was done by Thomas W. Dreschel and Christopher S. Brown of The Bionetics Corp. for **Kennedy Space Center**. *To obtain a copy of the report, "Porous tube plant growth nutrient delivery system for the Space Shuttle mid-deck locker Plant Growth Unit (PGU)," Circle 13 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 20]. Refer to KSC-11536.

Isotonic and Isokinetic Exercise During Bed Rest

Brief, intense activity prevents deterioration of peak oxygen uptake, a measure of work capacity.

Regular, high-intensity isotonic leg exercise maintains peak oxygen uptake at normal levels during extended periods of bed rest, but high-intensity isokinetic exercise does not, a study has found. The study, which is described in detail in the report, was intended to explore the effectiveness of exercise in maintaining fitness during long missions in microgravity so that crewmembers will be able to keep up the arduous work of building and expanding the Space Station.

In the study, 19 male volunteers, 32 to 42 years old, were confined to bed for 30 days in a 6°-head-down position. Five subjects did no exercise. Seven did isotonic leg exercise (cycling). Seven did isokinetic exercise (knee flexion and extension) on a Lido ergometer. The exercise was done in a supine position for two 30-minute periods a day. Various power levels were used for isotonic exercise, including some near the peak for each subject, as measured before bed rest began. The isokinetic exercise was done in sets of maximal contractions.

The subjects' peak oxygen uptake, heart rate, and volumes of plasma and red blood cells were measured frequently. Other tests included ultrasound and magnetic imaging of the legs to measure changes in muscles; magnetic imaging spectroscopy of the arms and legs to measure changes in the energy states of the muscles; and measurements of the concentrations of hormones in blood, the densities of bones, the calcium contents of cells, the composition and fluid balance of the body, cognitive performance, and mood.

For the subjects who did not exercise, the peak oxygen uptake fell an average of 18.2 percent during the 30 days. For those

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who did isotonic exercise, it rose an average of 2.6 percent. For the group that performed isokinetic exercise, it fell by 9.1 percent.

The study showed that intermittent, intense exercise of short duration is more effective than is similar exercise at lower intensity for longer times measured in previous studies. Although the precise reason is not clear, intense short-term exercise seems to maintain the volumes of plasma and red blood cells at normal levels.

This work was done by J. E. Greenleaf of **Ames Research Center**, *C. E. Wade of the Letterman Army Institute of Research, and E. M. Bernauer, T. S. Trowbridge, and A. C. Ertl of the University of California at Davis. To obtain a copy of the report, "Work Capacity During 30 Days of Bed Rest With Isotonic and Isokinetic Exercise Training," Circle 3 on the TSP Request Card.*
ARC-12180

Temperature Affects Fatty Acids in *Methylococcus Capsulatus*

Cis/trans ratios of monounsaturated fatty acids in membranes vary with temperature.

According to a report, the temperature of growth of the thermotolerant, methane-oxidizing bacterium *Methylococcus capsulatus* (Bath) affects both the proportion of monounsaturated fatty acids and the *cis/trans* ratio of these acids in the cell membrane. Because a suboptimum growth temperature is a potential stress factor, it may be possible to use such *cis/trans* ratios as indices of the stresses upon methane-oxidizing microbial communities, which are believed to play a major role in the nitrogen cycle and in the degradation of complex (particularly hydrophobic) organic compounds. In addition, research in the microbiology of methanotrophs is increasing because of the possible commercial exploitation of these organisms as biocatalysts or as sources of useful polymers; knowledge of the effect of temperature on the ability of methanotrophs to utilize methane may be useful in the optimization of conditions of growth.

In experiments described in the report, cultures of *M. capsulatus* (Bath) were grown in a mineral-salts medium with a continuous flow of a gaseous mixture of equal parts of methane and air at temperatures of 30, 37, and 45 °C. Cells in the early stationary phase were harvested by centrifugation, and the lipids were extracted. Methyl esters of the lipids were analyzed by gas/liquid chromatography. Monoenoic methyl esters were separated into *cis* and *trans* fractions by thin-layer chromatography on soft silica gel G plates impregnated with silver nitrate. The zones that corresponded to *cis* and *trans* unsaturates were eluted from the silica gel by use of chloroform, and the distribution of the isomers was determined by gas chromatography. The positions of the double bonds of *cis* and *trans* monoenoics were determined by ozonolysis followed by gas/liquid-chromatographic analysis of the fragments.

From the results of these analyses, it was concluded that *M capsulatus* (Bath) grew most readily at 45 °C: the cell yields were greatest at this temperature, and the doubling time at this temperature (3.8 h) was approximately a third of the doubling time at 30 °C (13 h). Growth at 30 °C resulted in the highest proportion of monounsaturated fatty acid (about 71 percent), with a *cis/trans* ratio of 1.3. Growth at 37 °C and 45 °C resulted in higher *cis/trans* ratios (8.1 and 6.5, respectively) and enhanced synthesis of the Δ11 and Δ12 positional isomers of the 16-carbon monounsaturate (where the number that follows Δ denotes the position of the double bond relative to the carboxylic end of the molecule).

This work was done by Linda L. Jahnke of **Ames Research Center**. *For further information, Circle 19 on the TSP Request Card. ARC-12792*

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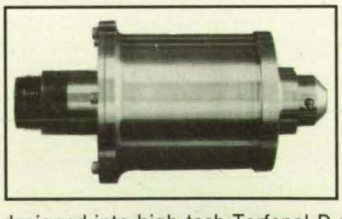

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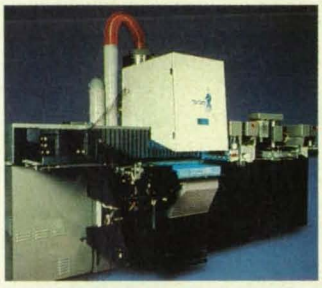
For More Information Circle No. 592

New on the Market

Cubital America Inc., Troy, MI, has unveiled the Solider 5600 **Data Front End (DFE) workstation** designed to increase the productivity of rapid prototyping systems. It enables on-site performance of such operations as subdividing large objects, stitching cracks between surfaces, increasing surface thickness, and eliminating redundant facets as well as Boolean operations between objects. The DFE's range of data formats includes ASCII, binary STL, SDRC's Universal files, AutoCAD's DXF, Digital Terrain Models, and VDAFS.

For More Information Circle No. 800



The Nifty Fifty, a 50 MHz 486 DX2 color LCD **notebook PC**, has been introduced by Ergo Computing Inc., Peabody, MA. It offers the speed, storage capacity, and expansion capability of a high-end desktop PC in a 6.7-lb. package (with battery) that measures just 8.5" x 11" x 2". Fully compatible with the MS-DOS, NT, UNIX, and OS-2 operating systems, the PC can be configured with 4, 8, or 16 MB of RAM. An optional expansion module accommodates two ISA 16-bit cards.

For More Information Circle No. 792

Kaman Instrumentation Corp., Colorado Springs, CO, has announced a **noncontact position sensing system** that can be customized to meet specific OEM requirements. The new SMU-9000 features sensors with measuring ranges to 40 mm, resolution to one part in half a million, 7.5 to 15 Vdc at 20 mA input power, and on-board voltage regulation.

For More Information Circle No. 780

A CFC- and methyl chloroform-free **release agent/dry lubricant** is available from Miller-Stephenson Chemical Co., Danbury, CT. MS-122N/CO2 is a Teflon-life, TFE release agent suited for polyurethanes, acrylics, polypropylene, phenolics, foams, rubber moldings, epoxies, polycarbonates, polystyrene, pre-preg fabrication, and filament winding. The material contains no silicones and produces no discernable transfer or migration.

For More Information Circle No. 796

Mizar Inc., Carollton, TX, has announced a **multiprocessor digital signal processing module** for the VMEbus capable of achieving peak speeds of 200 MFLOPS. The MS 7770 features four Texas Instruments TMS320C40 digital signal processors, which are fully interconnected for high-speed interprocessor communication. Each processor has three more 20-MB/sec communications ports to enable easy interconnection of multiple boards for such architectures as a 3D-mesh, ring, or hypercube.

For More Information Circle No. 788

HyperConverter, a stand-alone board from Expert Graphics, Atlanta, GA, enables easy and cost-effective **conversion of high-resolution computer graphics to NTSC- or PAL-compatible video.** The board automatically accommodates any input resolution up to 1024 x 768, 76 Hz (noninterlaced) in Super VGA, VGA, 8514, and XGA. Also capable of handling 16 and 24 bit graphics, it crisply reproduces images on a standard television set.

For More Information Circle No. 784

Workstation Technologies Inc., Irvine, CA, has introduced the WTI-*PrimeTime*™, a self-contained **television tuner** that gives desktop computers access to broadcast and cable video signals. Targeted for system integrators and OEMs, the tuner is available for Macintosh, IBM, and IBM-compatible computers; receives both UHF/VHF antenna input and cable signals in real time; and provides output to video digitizing cards.

For More Information Circle No. 786

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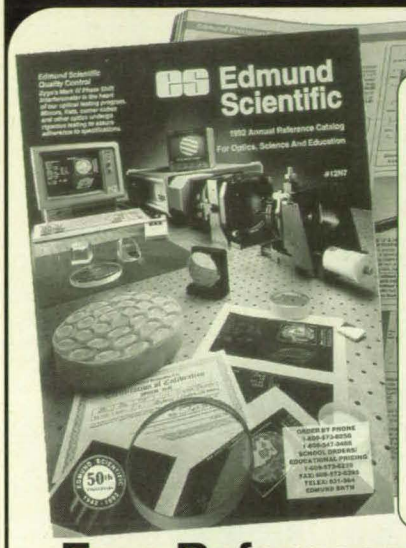

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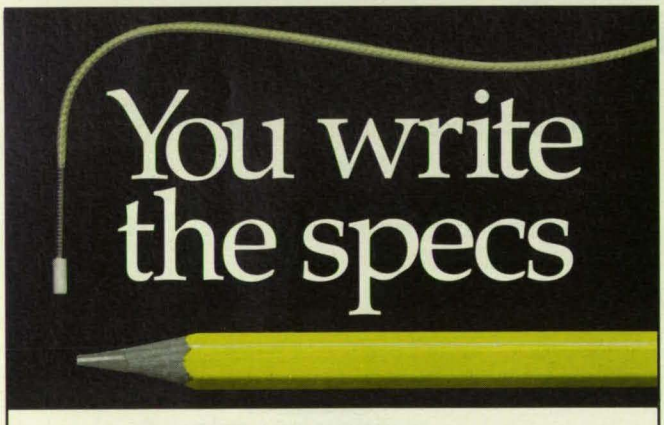

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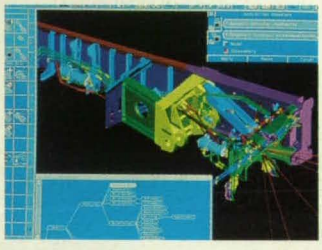
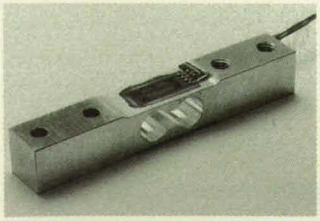
New on the Market

Applied Data Systems Inc., Baltimore, MD, has engineered a palm-size **32-bit RISC-based video display system** for embedded applications. Dubbed the Pixel Press, the 3.1" x 5.1" module contains a 32-bit processor, 786 KB of EPROM, a parallel interface, an RS-232 debug port, and a voltage supervisor. Requiring just 700 ma at 5 volts, it provides a video output of 1024 x 768 non-interlaced resolution with 16 colors.
For More Information Circle No. 774

A stand-alone, high-performance, multi-platform **project visualization system** is available from Computervision Corp., Bedford, MA. The CVpvs™ allows AEC, mechanical, and manufacturing users to visualize any large-scale 3D CAD project to gain a better understanding of structure and appearance from every angle. At any stage of development, users can perform dynamic shaded viewing, animation, and 3D model simulations.
For More Information Circle No. 782



The FSU **force sensor** from NMB Technologies Inc., Chatsworth, CA, accurately measures weight and force in consumer and industrial products. Comprising a full strain-gauge Wheatstone bridge installed on a small aluminum bending beam, the sensor is available in rated capacities from 2.2 pounds to 1 pound with normal output of .5 mv/V. The FSU's .5" height permits its use in compact designs.
For More Information Circle No. 790



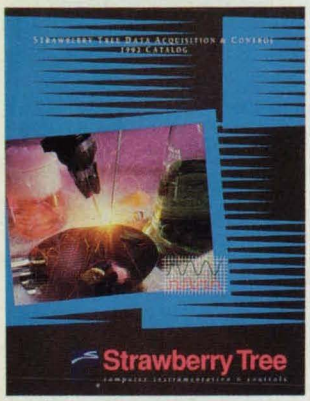
Digital Equipment Corp., Maynard, MA, has unveiled Alpha AXP—an advanced **64-bit computing architecture** comprising a complete set of systems, software, applications, and services. The universal platform offers a choice of three open software environments as well as open standards and hardware and network interconnects. Alpha AXP is designed to run commercial and scientific applications faster and at a lower cost and to explore advanced applications such as virtual reality, multimedia, artificial intelligence, simulation, and voice recognition.
For More Information Circle No. 778

BeamCAD and BeamCAD Plus **software for modeling laser beam propagation through optical systems** has been released by Coherent Instrument Division, Auburn, CA. The user specifies the beam characteristics (M^2, waist diameter and location, and wavelength), then the software calculates beam width, wavefront radius of curvature, distance to beam waist, and Rayleigh range at each point specified in the optical system.
For More Information Circle No. 794

SpectraSource Instruments, Westlake Village, CA, has developed a series of low-cost 12-bit **CCD imaging systems**. The HPC-2 and MCD-1200 models, tailored for low-light and medical applications, offer image digitization at 325 kilo pixels per second and feature low read-out noise, low dark current, and wide dynamic range. The MCD-1200 enables scripting, external device triggering and control, and automatic multi-frame sequencing.
For More Information Circle No. 798

The industry's first family of **switching regulator power ICs** to break the 1 MHz barrier has been introduced by Harris Semiconductor, Melbourne, FL. At 1 MHz, the three HIP506X series chips can switch up to ten amps at 60 volts DC in less than three nanoseconds with ultra-low switching losses. They permit designers to employ current mode controlled PWM (pulse width modulation) fixed frequency switching techniques to produce miniaturized power supplies exceeding 1 MHz.
For More Information Circle No. 776

New Literature



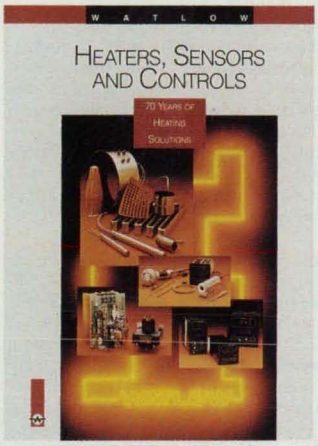
Strawberry Tree Computer Instruments & Controls, Sunnyvale, CA, has published a catalog of **data acquisition and control** products for MS-DOS and Macintosh computers. The company's high-performance plug-in boards feature software selection of input type with built-in linearization, automatic calibration, and self-diagnostics. Icon-based WorkBench software permits easy measurement, analysis, and control with no programming.
For More Information Circle No. 714

A four-color brochure from DFI Pultruded Composites Inc., Erlanger, KY, outlines its **pultruded composites** capabilities and depicts pultruded structural profiles for various applications. The publication provides criteria for fiber selection, form, and placement; reviews the advantages of carbon reinforcing fibers; and discusses composite tolerances and the manufacturing expertise necessary to achieve them.
For More Information Circle No. 706

A 460-page **measurement and control** design handbook and buyer's guide has been published by EIL Instruments Inc., Hunt Valley, MD. Featured products include sensors, transducers, transmitters, controllers, counters, timers, ratemeters, analog and digital displays, recorders, data loggers, and test equipment.
For More Information Circle No. 708

The Tango line of DOS-based **electronic design automation (EDA) software** for PCs and compatibles is described in a brochure from ACCEL Technologies Inc., San Diego, CA. The EDA tools feature schematic-entry, various levels of packages for printed circuit board layout and autorouting, and programmable logic device design.
For More Information Circle No. 710

Heaters, sensors, and controls are showcased in an 850-page catalog from Watlow Electric Manufacturing Co., St. Louis, MO. Featured heaters include band and nozzle, cable, cartridge, ceramic fiber, flexible, radiant, strip, and tubular and process assemblies. Also highlighted are infrared sensors, ramping controls, microprocessor-based digital controls, alarms and limits, thermostats, and power switching devices.
For More Information Circle No. 702



Federal Marketing Services Inc., Rockford, IL, has released two new **ISO-9000 training** volumes. The *All About ISO-9000 Workbook* reviews the purpose and benefits of ISO-9000 and provides guidelines for swift and cost-effective certifications, audits, assessments, and documentation. The *How To Write Your ISO-9000 Manual* trains management teams in the basics of the certification process, documentation, details of the ISO-9001 standard, formats, and reference methods.
For More Information Circle No. 712

A brochure describing the scientific data analysis capabilities of LabVIEW and LabWindows **instrumentation software** is offered by National Instruments, Austin, TX. The programs feature libraries for spectral, time, numerical, statistical, and regression analysis. They are easily customized and integrated for applications in medical monitoring, vibration analysis, process control, data acquisition, and test and measurement.
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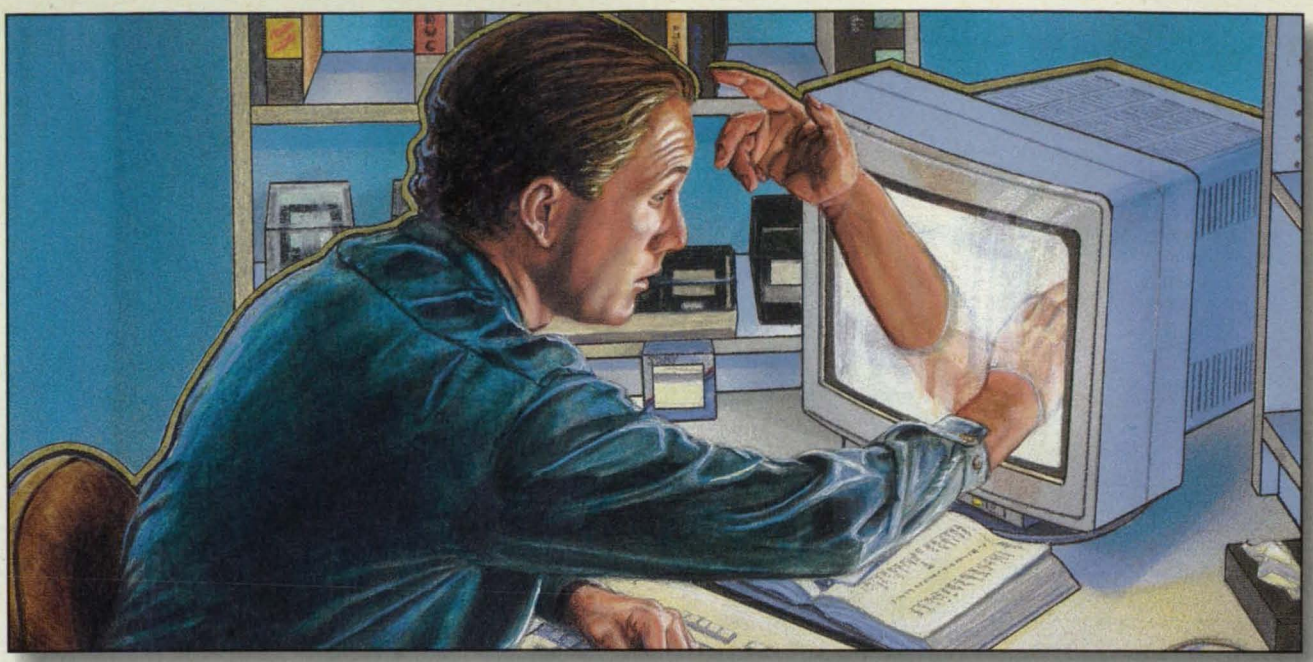

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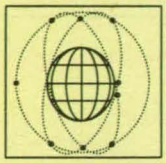

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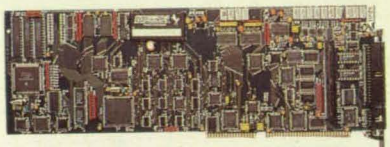

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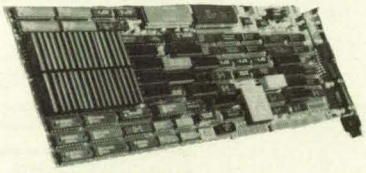

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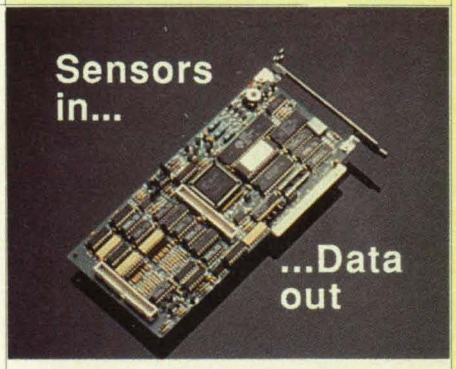

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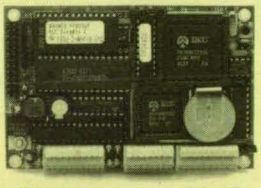

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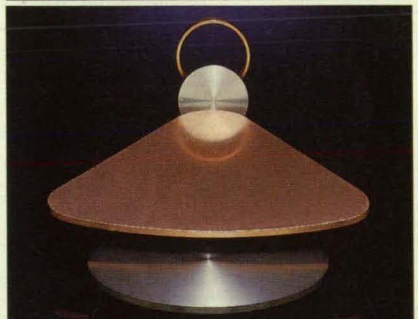

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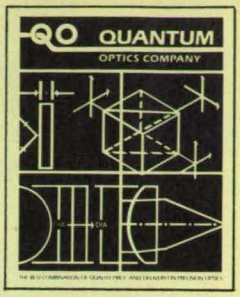

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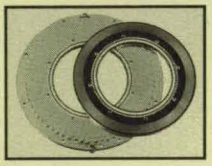

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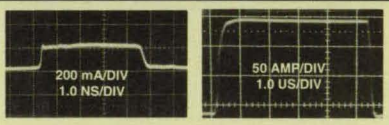

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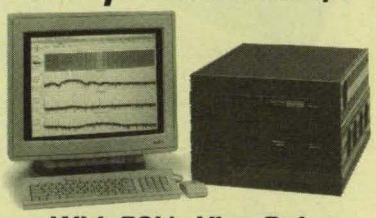

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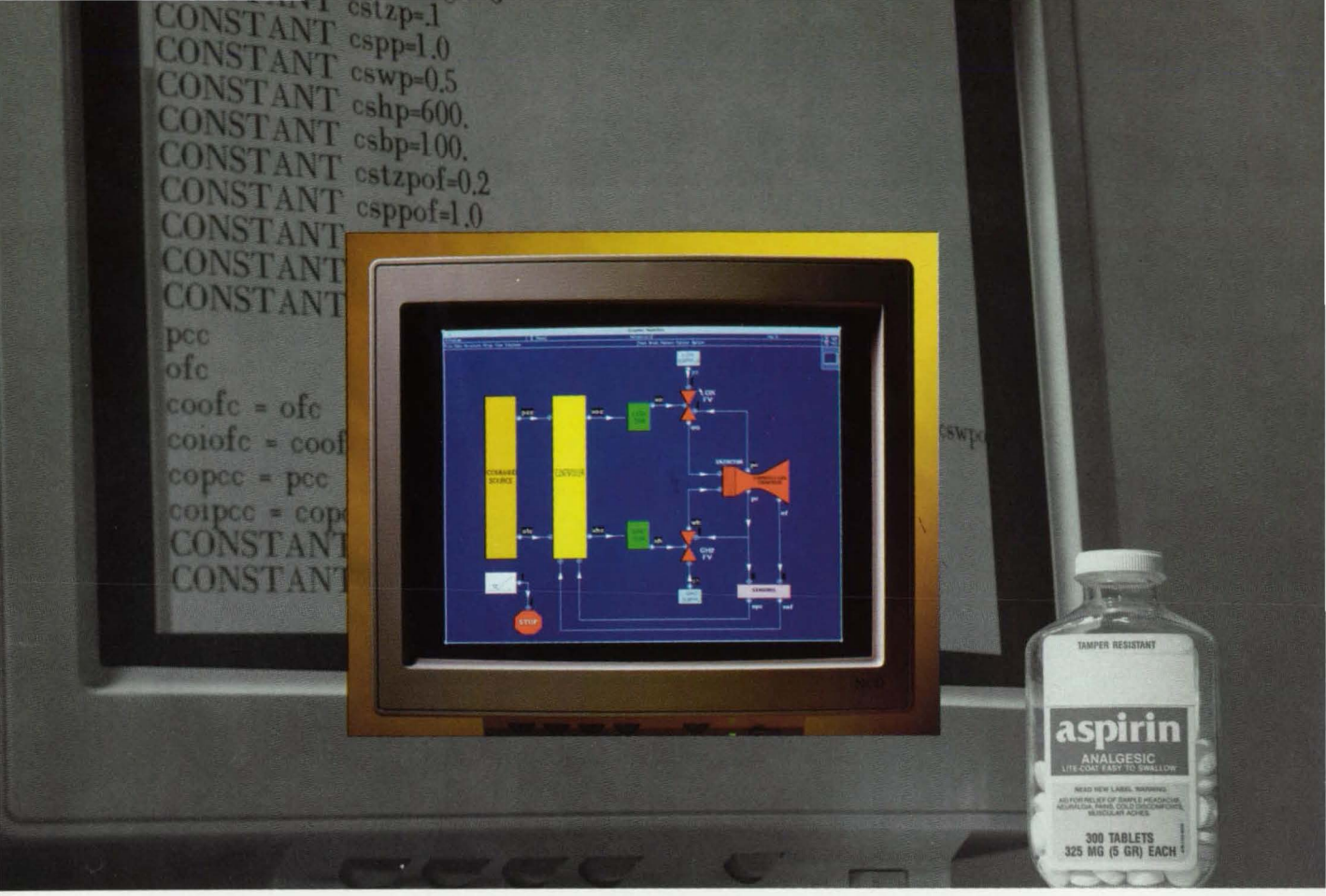

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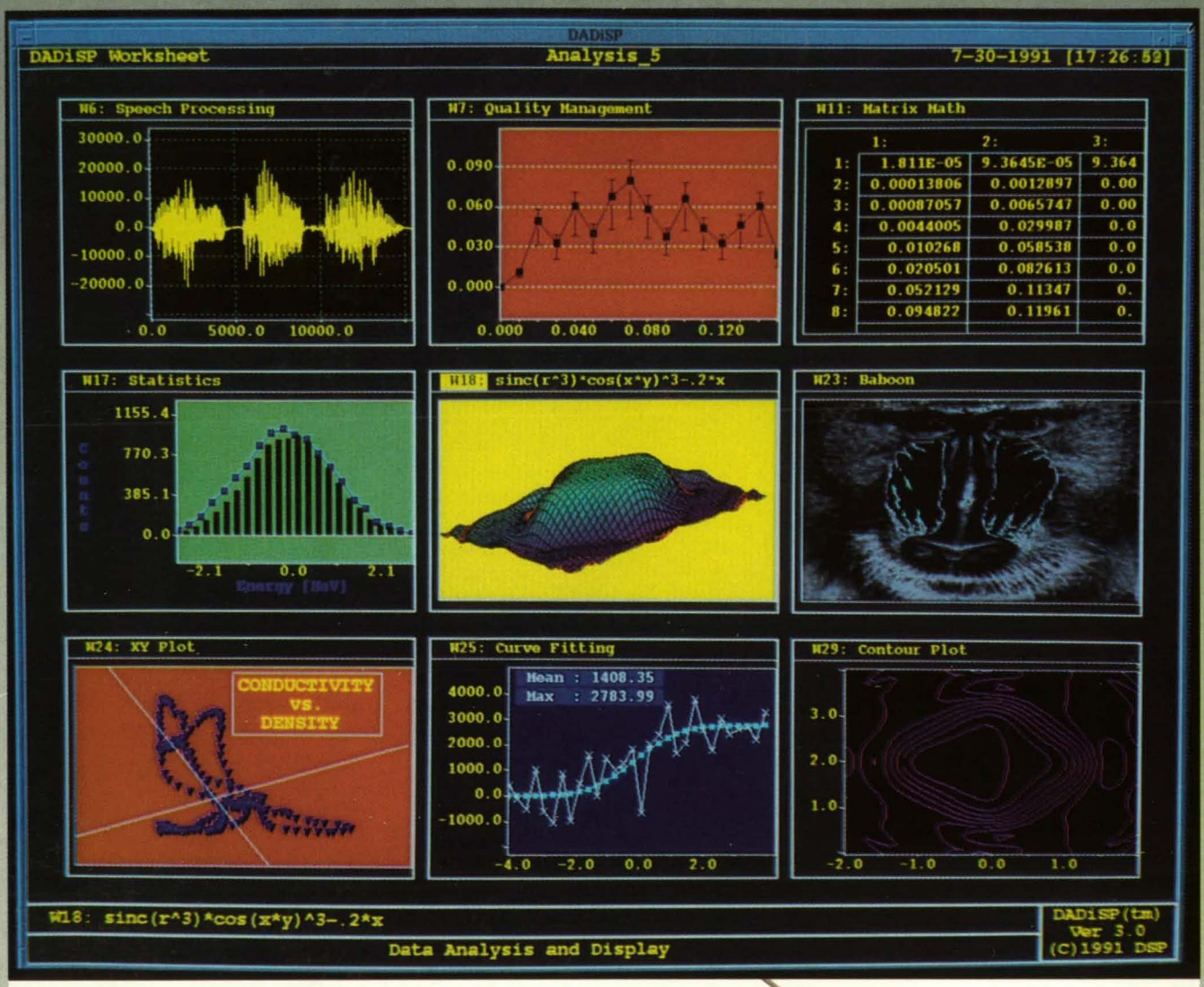

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